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The WELDING Journal

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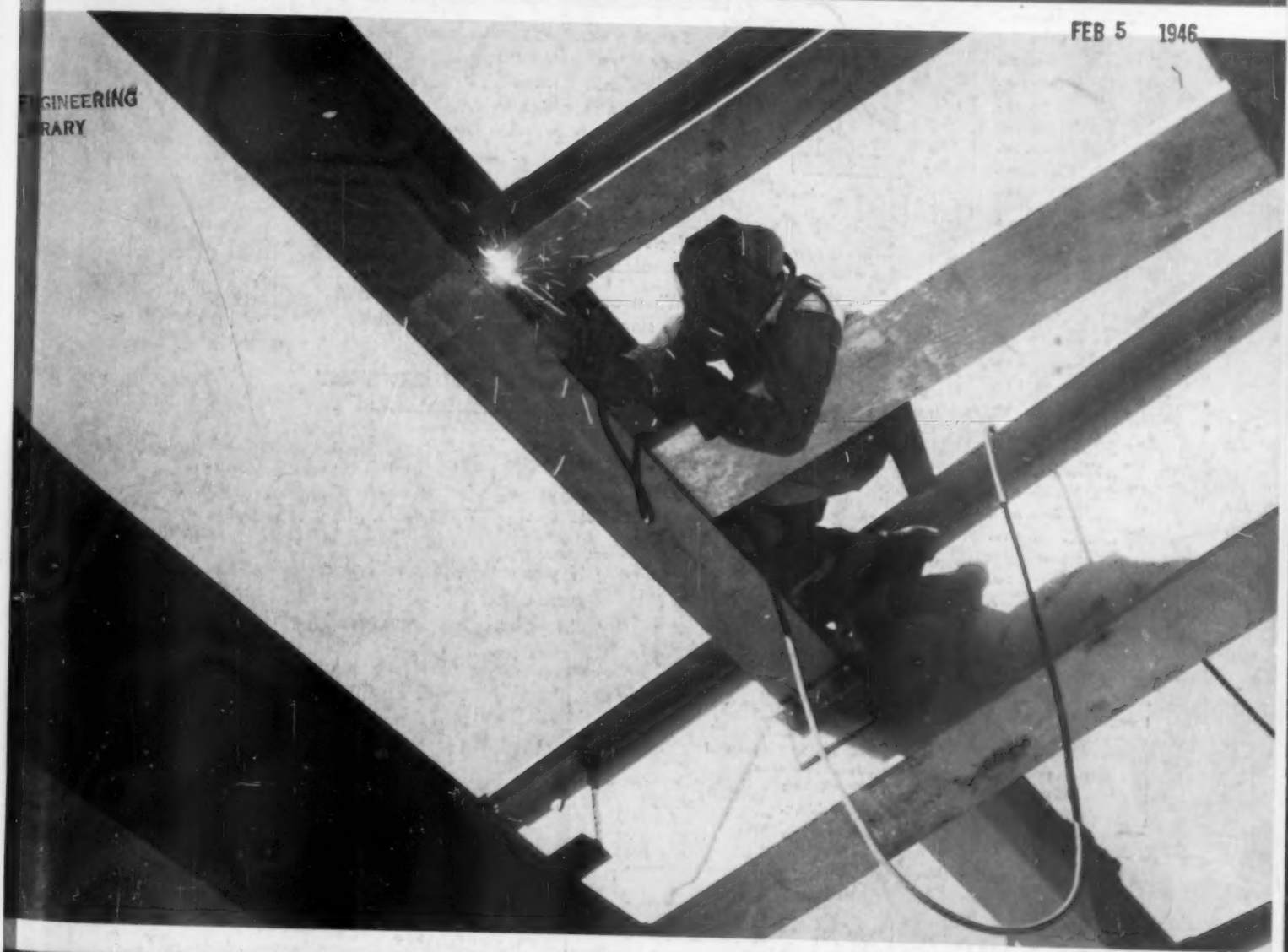

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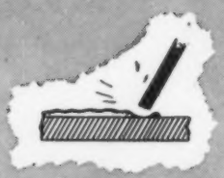

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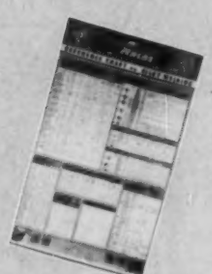

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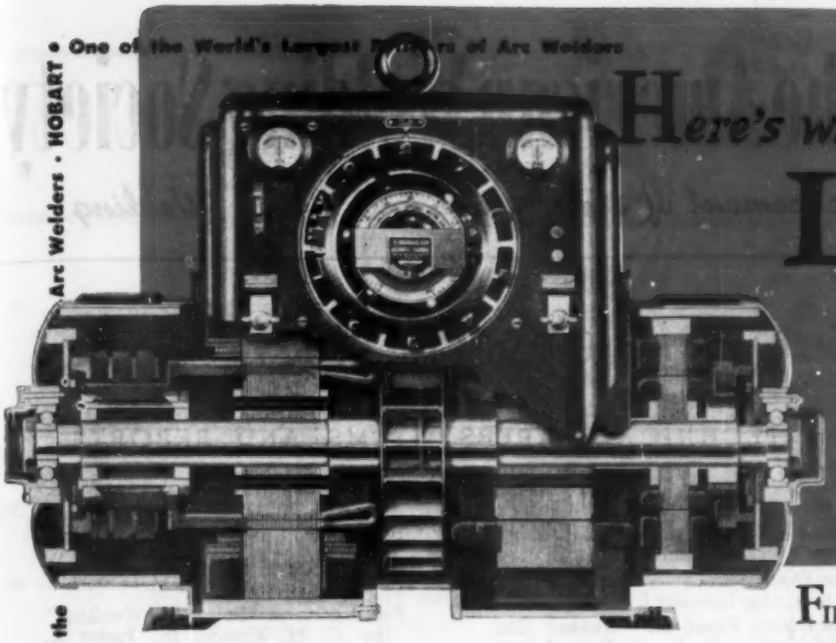

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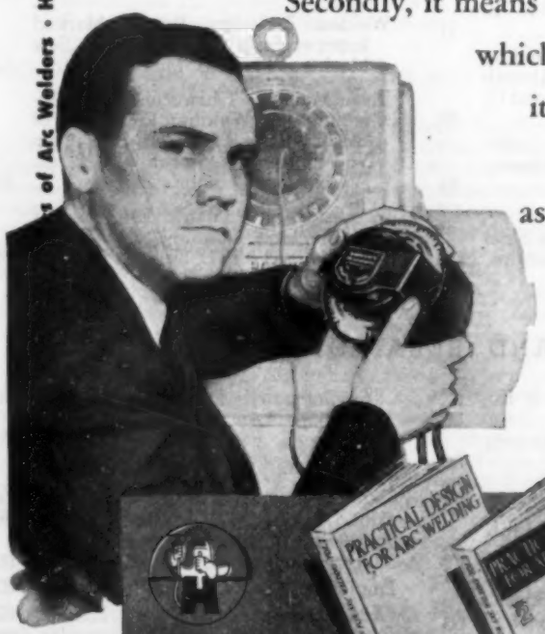

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Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

JANUARY, 1946

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COVER

Overhead Welding of Floor Beams on Bridge Structure. *Courtesy, The Lincoln Electric Company.*

ISSUED MONTHLY

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CONTENTS

TECHNICAL PAPERS, ITEMS AND REPORTS

The Design and Methods of Construction of Weld Steel Merchant Vessels 5
Flame-Hardening in the Small Shop, by William B. Sharav 19
The Steel Warehouse and Flame Cutting, by Leonard J. Quetsch 24
Discussion Paper on "Welded Gas Holders with Panel Type Lifts," by Geo. F. Wolfe 25
Induction Heating Brazes Tool Tips, by T. A. Vernor and E. F. Adams 26
The Application of Pressure Welding to Overland Pipe Lines, by E. P. Jones 27
Discussion on "Shop Notes on Welding Stainless Steel," by J. B. Arthur 31
Discussions on "The Heliarc Welding Process as Applied in the Aircraft Industry," by F. R. Shanley and C. T. Fallon 32
Welded Design as Applied to Lightweight Army and Navy Structures, by H. A. Oldenkamp 33
Current Welding Literature 37
Resistance Welding on Stainless Steel Aircraft Engines and Accessories, by Frank G. Harkins and W. L. Hales 39
Discussions on "Maintenance and Repair on Oil Pipe Lines," by A. N. Kugler, H. C. Price, P. M. Mattern 46
Discussions on "Power for Welding," by C. M. Rhoads, Jr., Foster R. Woodward, R. E. Young 47
Discussions on "Some Fundamentals in All-Welded Ship Construction," by E. M. MacCutcheon, Jr., John Vasta, H. W. Pierce 49
Alternating and Direct Current, by Lee Cline 51
Welded Redesign Brings Marked Improvements to Electric Meat Saw Machine, by J. S. McKeighan 53
Discussions on "Chemical Factors Affecting the Welding Properties of Stabilized 18-8 Stainless Steel," by V. Whitmer, Stephen F. Urban, G. F. Comstock, Author's Reply 56
Discussion on "Electric Eye Tracing in Machine Cutting," by C. M. Underwood & E. D. Debes 58

SOCIETY AND RELATED ACTIVITIES

27th National Metal Congress & Exposition 60
A.S.M.E. Presents Honors and Awards at Annual Dinner 60
Charles Schenck Retires 60
Axtell Joins Progressive Welder 62
Three Promoted at East Pittsburgh Plant 62
INDEX TO ADVERTISERS 64
A.C. Arc-Welding Machine Booklet 66
Selection of Arc Welding Electrodes 68
Chart on Alloy Welding 68
Welding Manual 68
Founder of Lincoln Electric Honored on Company's Fiftieth Anniversary 70
New Chart Lists Welding Electrode Properties 70
Gas Holders 70
New Products 72
Bound Volume Journal 76
Abstracts of Current Welding Patents, Prepared by V. L. Oldham 80
Employment Service Bulletin 82
Guide to Everyday Welding 82
Section Activities 86
List of New Members 90
Members Reclassified 94

WELDING RESEARCH SUPPLEMENT

Graphitization of Carbon-Molybdenum Steel in High-Temperature Steam Piping, by George A. Timmons 1-s
The Flash Welding of Alclad 24S-T Alloy in the 0.064-In. Thickness, by W. F. Hess and F. J. Winsor 9-s
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The Effect of Triaxiality on the Technical Cohesive Strength of Steels, by George Sachs and J. D. Lubahn 53-s

The Journal of
The American Welding Society
VOLUME 25 • NUMBER 1 • JANUARY, 1946

The Design and Methods of Construction of Weld Steel Merchant Vessels*

UNITED STATES COAST GUARD
WASHINGTON 25, D. C.

ADDRESS REPLY TO
THE COMMANDANT (E)

REFER TO FILE:
30 July, 1945

To: The Secretary of the Navy.

Subj.: Second Interim Report of the Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels.

Ref.: (*a*) Secretary of the Navy's Letter of 20 April, 1943.

1. On 3 June, 1944, the Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels, convened in compliance with reference (*a*), submitted its First Interim Report. The Board, at that time, gave its unqualified opinion that "without early and general adoption of welded construction in the merchant shipbuilding program, as well as in the naval shipbuilding program, the results in speed and volume of construction which have been accomplished would have been impossible."

2. Events since that time, as outlined in the inclosed Second Interim Report, confirm most completely this opinion. During the intervening months numbers of ships of more or less completely welded construction and of a wide variety of types built during the full pressure of a critical war period have gone into the most severe service. The results overall and in the very great majority of individual ships have been excellent beyond reasonable expectation.

3. The problems of welded ship design and construction are not, however, completely resolved and the Board believes that it is desirable that it remain in being for the present and until additional phases of its research and study are completed, when a final report will be submitted.

4. Approval of this report is requested.

[SIGNED]

HARVEY F. JOHNSON
Rear Admiral, U.S.C.G., Chairman

E. L. COCHRANE
Vice Admiral, U.S.N.

H. L. VICKERY
Vice Admiral, U.S.N.

DAVID ARNOTT, *Vice-President-Chief Surveyor, American Bureau of Shipping*

Incl.:
Second Interim Report

THE SECRETARY OF THE NAVY
WASHINGTON

Sept. 21, 1945

To: Rear Admiral H. F. Johnson, U.S.C.G.
Chairman, Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels
Room 5202
1300 E Street, N.W.
Washington 25, D. C.

Subj.: Second Interim Report of the Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels.

Ref.: (*a*) Sec. Nav. ltr. of 20 April 1943 (Precept).

(*b*) Second Interim Report to Sec. Nav. dated 30 July 1945.

1. The Secretary of the Navy notes with satisfaction the marked improvement in the experience with the all-welded steel merchant vessels during the interval from 1 February 1944 to 1 February 1945 which indicates the effectiveness of the corrective measures developed under the leadership of the Board. The request of the Board to be permitted to remain in being until the additional phases of its research and study are completed is approved. It is desired that a further report be submitted by 1 March 1946, and it is hoped that the work of the Board will have been completed by that time.

2. The report, reference (*b*), is approved for release to the press.

[SIGNED]
FORESTAL

SINCE the date of the First Interim Report of the Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels nearly a year of service experience has accumulated, during which the Board has continued active investigation of all aspects of the problems discussed in that report. It appears desirable, therefore, to issue a Second Interim Report at this time.

Nothing has occurred to vitiate the general conclusions with respect to the over-all problems as set forth in the introduction of the First Interim Report.

This report is arranged in accordance with the outline used for the First Interim Report. In addition, there are submitted with this report five exhibits:

Exhibit I—Tabulation of Data on Ships Which Sustained Potentially Serious Structural Failures and Reports of Certain Vessels Which Sustained Complete Fractures of Strength Deck.‡
Exhibit II—The Structural Alterations of Liberty Ships.†
Exhibit III—Full-Scale Bending Tests.‡
Exhibit IV—Survey of Research Projects.
Exhibit V—Survey of Shipyard Welding Practices.‡

---

* Abstract of Second Interim Report dated May 1, 1945 of a Board of Investigation convened by order of the Secretary of the Navy.
† Not reproduced. See First Report published in the September 1944 issue of THE WELDING JOURNAL, p. 794.
‡ Only partially reproduced in this abstract.

A. Historical Study of Recent Hull Fractures

1. *Statistical Analysis*

No vessels have been lost due to hull fractures since the last report. Since the preparation of the First Interim Report certain circumstances surrounding the investigation of welded ships have changed, as stated below:

	April 1, 1944	Feb 1, 1945
Total number of ships launched	2993	4063
Total number of the above ships which sustained fractures	432	722
Total cases of fractures	572	1045
Total cases of potentially serious fractures	95	102
Total cases sustaining a complete fracture of strength deck	20	23

The number of months afloat accumulated by the representative group for each potentially serious case has shown improvement, as illustrated in Fig. 1. The

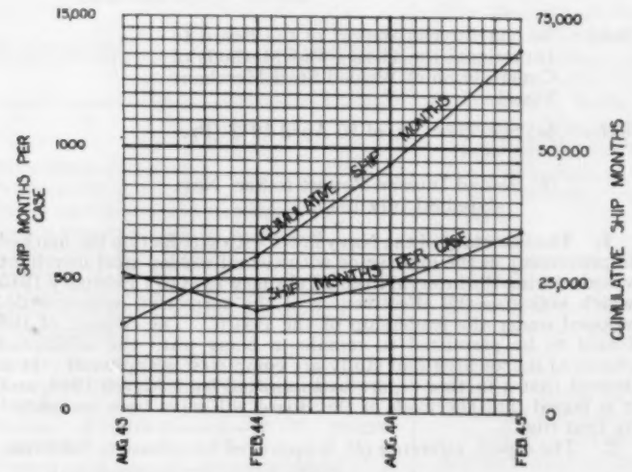


Fig. 1—Ship Months for Each Potentially Serious Case

number of ship months per case had increased from 379 at February 1, 1944, to 672 at February 1, 1945.

The reported rate of incidence of casualty has markedly decreased during the winter months, as compared with the corresponding months of the preceding year. The figures are as follows:

December 1943	72	December 1944	11
January 1944	107	January 1945	13

The numbers of potentially serious cases each month are shown in Fig. 2. In December 1943 and January 1944 a total of 38 cases occurred compared to a total of 3 cases for December 1944 and January 1945.

The statistical studies of the nature and incidence of fractures are still being kept up to date with further breakdown intended to indicate the effect of the several corrective measures which have been put into effect on existing vessels and the revision in details which have been made for new construction. The structural alterations to minimize notch effect of square hatch corners referred to in the previous report, as described herein, Exhibit II, were completed on about 1126 ships of Liberty type under construction and to about 371 such ships in service. Of these 1497 ships only 22 incurred fractures in the vicinity of hatch corners. In contrast there have been fractures in the vicinity of hatch corners on about 194 of 1078 ships which did not have the structural alterations above mentioned. While the statistics with respect to hatch corners show a more favorable trend, it is important to note that in a majority of cases the vessels altered had not completed a full cycle of seasons.

With respect to longitudinal riveted joints provided for the purpose of resisting the progression of cracks once started, the evidence to date is insufficient to permit drawing any conclusions as to their effectiveness.

Fractures which were subject to complete examination since submission of the last report in all cases indicate the origin to be in discontinuities occasioned by design details and notch effects incidental to imperfect welding.

2. *Specific Cases*

Exhibit I, attached hereto, represents a tabulation of data on ships which sustained potentially serious structural fractures and detailed reports on 16 of the ships which sustained a complete fracture of the strength deck.

B. Design

1. *General*

The reports included in Exhibit III, Full-Scale Bending Tests, furnish confirmation of the statement made in the First Interim Report that the "scantlings of all affected classes have been re-examined and are found to have a margin of strength over the requirements of the internationally accepted standards." In addition, hog-sag tests were conducted on the "Philip Schuyler" by the Maritime Commission in June 1944, the results of which are now being analyzed.

2. *Detail*

No further changes in structural design details have been adopted since the date of the First Interim Report. Research on design detail is covered in Exhibit IV.

C. Materials

1. *Base Metals*

No change has occurred in the situation with respect to base metals except that investigations of base metals are progressing as indicated in Exhibit IV.

2. *Welding Electrodes*

The Welding Advisory Committee found there was little misapplication of the various types of welding electrodes in shipyards. However, the classification of welding electrodes was not clear and several of the electrodes

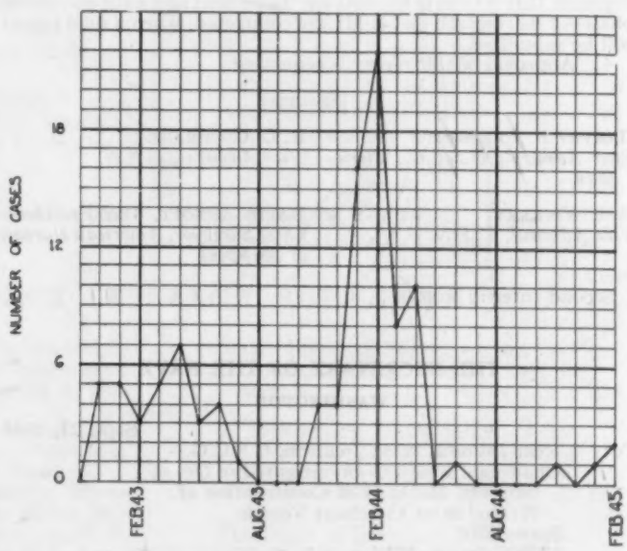


Fig. 2—Potentially Serious Structural Failures

had two or three classifications. The revised welding electrode specifications, issued jointly by the American Bureau of Shipping and American Society for Testing Materials for 1945, provide that a welding electrode shall meet and have but one classification. In this and most other respects these specifications are in substantial agreement with the revised specifications for the Bureau of Ships, Navy Department for 1945.

Revision of the existing welding electrode listings was necessary in order to establish each rod under a single correct classification. Steps have also been taken jointly by the Maritime Commission, American Bureau of Shipping, U. S. Army, Bureau of Ships of the Navy Department and the U. S. Coast Guard to enforce the two-color marking of electrodes adopted as a standard September 3, 1942, by National Electric Manufacturers Association. Two-color markings of welding electrodes will enable the identification of each type of electrode on sight and should help to prevent their misapplication.

Restrictions as to sizes and use of electrodes of the E-6012 and E-6013 classification for use in merchant vessels and their equipment are now in effect.

The standardization of specifications, including not only the physical requirements for the electrodes but also the method to be used in demonstrating such qualities, the proper AMERICAN WELDING SOCIETY and American Society for Testing Materials designations, and the permissible applications of several types of electrodes, has effected a desirable uniformity in the administration of requirements by each of the regulatory bodies. The collaboration which has brought about the foregoing standardization is continuing in joint research activities.

D. Construction

For the purpose of investigating the construction methods and quality of workmanship in shipyards of the United States, a Welding Advisory Committee was formed and made an investigation in 33 shipyards on the East Coast. The results of the investigation are set forth in a Sub-Board Report, Exhibit V. Attention is invited to the statement in the Sub-Board Report that the four parent agencies are collaborating in further investigations and in taking remedial measures as indicated. These agencies have jointly compiled a booklet entitled "Shipyard Welding Workmanship" which is being widely distributed and should be of considerable educational value to the individual welders.

E. Operating Conditions

1. Loading and Ballasting

The War Shipping Administration has instituted the following practices pertaining to ballasting on Liberty and Victory type ships:

(a) Liberty Ships.—Solid ballast required, as listed in Column (1), for summer crossings for ships leaving with no cargo, but with all tanks full.

Solid ballast is required, as listed in Column (2), for winter crossings of North Atlantic and Alaskan waters for ships leaving with no cargo but with all tanks full.

	(1)	(2)
No. 2 Tween deck	110 tons	185 tons
No. 2 Hold	250 tons	350 tons
No. 3 Tween deck	180 tons	230 tons
No. 3 Hold	435 tons	585 tons
No. 4 Tween deck	160 tons	185 tons
No. 4 Hold	365 tons	465 tons
Total	1500 tons	2000 tons

(b) Victory Ships.—Solid ballast as follows is required for winter crossings, northern waters, for ships leaving with no cargo but with all tanks full:

No. 1 Hold	350 tons
No. 2 Upper tween	250 tons
No. 3 Upper tween	250 tons
No. 4 Hold	140 tons

The amounts and location of solid ballast noted above have been predicated primarily on obtaining satisfactory drafts for seaworthiness under convoy conditions. The distribution of this ballast fore and aft is such as to minimize hogging stresses in a seaway.

2. Weather, Course, Speed and Sea Routes

There has been a reduction in the number of casualties on ships traveling in ballast, tending to indicate that the above requirements are beneficial. Although sufficient data are not available to permit statistical analysis it appears possible that the proportion of ships operating in cold waters and the rougher ocean areas has decreased materially and that this factor may have contributed to the reduction in casualty rate. It is planned to conduct further investigation of this phase of the problem.

F. Specific Investigations

In August 1944 the Board appointed a Research Advisory Committee under the chairmanship of Mr. G. S. Mikhalapov of the National Research Council War Metallurgy Committee. All of the research projects mentioned in the First Interim Report have been assigned to the Research Advisory Committee for coordination of effort and evaluation of results. The first report of this committee is included herewith as Exhibit IV. Attention is invited to the fact that the conclusions so far reached are tentative and subject to further verification.

G. International Exchange of Information

International exchange of information has continued in increasing volume and has proved most helpful to investigators in this country and in Great Britain.

Exhibit I

There follows a tabulation of data on ships which sustained potentially serious structural failures and reports of certain vessels which sustained complete fractures of Strength Deck, February 1, 1945.

Exhibit III

FULL-SCALE BENDING TESTS

The over-all strength of the hull girder was probably the first item suspected when the structural failure problem arose on the ships. Calculations were made to compare the over-all strength of the current Maritime Commission welded ship designs with similar vessels which had exhibited satisfactory performance in service. These calculations indicate that the over-all strength of the designs in question is equal to that of successful riveted vessels and, furthermore, that the hull girder strength exceeds internationally accepted standards.

The validity of a direct comparison between welded

POTENTIALLY SERIOUS STRUCTURAL FRACTURES

NAME OF VESSEL	TYPE	YARD	LAUNCHING DATE	MONTHS AFLOAT	CASUALTY DATE	LOADING & DRAFTS	SEA CONDITION & DIRECTION	WIND FORCE	SHIP'S SPEED IN KNOTS	TEMPERATURE AIR/WATER	LOCATION OF FRACTURE	ORIGIN OF FRACTURE	REMARKS
ENDERS M. VOORHEES	BULK FREIGHTER NOT MC	GREAT LAKES Eng. Wks. RIVER ROUGE			10 NOV. '42	BALLASTED 12/3 - 21/8½	HEAVY	32 MPH	80 RPM	25°/42°	SHEER & STRINGER @ FR 136 STBD. & FR 130 PORT.	PROBABLY AT GUNWALE	COMPLETE FRACTURE OF STRENGTH DECK
JEREMIAH WADSWORTH	EC2 S-C1	TODD-HOUSTON CORP.	7 SEPT. '42	2	11 NOV. '42	LOADED	NORMAL PORT QTR			SPRING	SHEERSTRAKE FRS. 90-91	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
THOMAS MACDONOUGH	EC2 S-C1	OREGON SB CORP.	28 JAN. '42	9	14 NOV. '42	LOADED 27/5 - 29/0	HEAVY			AUTUMN	BULWARK SHEERSTRAKE & DECK TO WITHIN 6" OF #4 HATCH AT FORWARD STBD. CORNER	PROBABLY AT BUTT WELD OF BULWARK INSERT @	
JAMES McNEILL WHISTLER	EC2 S-C1	OREGON SB CORP.	30 SEPT. '42	1	28 NOV. '42	BALLASTED 7/1 - 18/0	HEAVY	9	1-2 K.	32°/42°	DECK AT AFT PORT END #3 HATCH; BULWARK SHELL & STRAKE BELOW FRS 81-82, BILGE STRAKE	PROBABLY AT DECK BUTT WELD 15" FROM HATCH CORNER; FRS. 74-75 UNKNOWN, UNLIKELY	
ALDEN GIFFORD	N3-S-A1	LEATHEM D. SMITH	2 AUG. '42	2	X NOV. '42	BALLASTED	NORMAL			AUTUMN	STRINGER & SHEERSTRAKE FOR 2'-0" OPPOSITE AFT END #3 HATCH, PORT	UNKNOWN	
GEORGE CHAMBERLIN	EC2 S-C1	OREGON SB CORP.	14 AUG. '42	3	1st DEC. '42	UNKNOWN	HEAVY	9-10		AUTUMN	STRINGER & ADJACENT STRAKE AT AFTER END OF #3 HATCH, STBD.	UNKNOWN	
HARVEY W. SCOTT	EC2 S C1	OREGON SB CORP.	19 JULY '42	4	5 DEC. '42	LOADED	NORMAL			SPRING	STRINGER, SHEER & STRAKE BELOW FRS 90-91 STBD.	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
JOHN C AINSWORTH	EC2 S-C1	OREGON SB CORP.	24 JULY '42	5	25 DEC. '42	BALLASTED 4/6 - 15/8	HEAVY CROSS	5	3-4 K.	40°/40°-46°	SHEER & STRINGER PLATES FRS 90-91	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
HENRY BALDWIN	EC2 S-C1	CALIFORNIA SB CORP.	18 OCT. '42	2	27 DEC. '42	LOADED	HEAVY	10	2K.	70°/	DECK AT FWD. PORT CORNER OF #3 HATCH & SHEERSTRAKE	PROBABLY AT HATCH CORNER	
WILLIAM T. SHERMAN	EC2 S-C1	OREGON SB CORP.	25 NOV. '42	1	27 DEC. '42	LOADED	HEAVY	8-9		WINTER	SHEERSTRAKE & STRINGER PLATES ABOUT FR. 128	UNKNOWN	
SCHENECTADY	T2-SE-A1	KAISER Co. Inc. SWAN ISLAND	24 OCT. '42	2	16 JAN. '43	BALLASTED 6/4 - 17/0	CALM			23°-38°/	DECK, SIDE SHELL & LONGITUDINAL BHDS. IN WAY OF #3 TANK.	DEFECTIVE WELD CONNECTING STBD. FASHION PLATE AND SHEERSTRAKE	BROKE IN TWO IN PORT - REPAIRED
DANIEL HEISTER	EC2 S-C1	TODD-HOUSTON CORP.	22 AUG. '42	4	1-12 JAN. '43	UNKNOWN	UNKNOWN			WINTER	SHEER & STRINGER PLATES FRS. 90-91	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
NICHOLAS GILMAN	EC2 S-C1	TODD-HOUSTON CORP.	25 JULY '42	5	3-4 JAN. '43	UNKNOWN	HEAVY			40°/	STRINGER & ADJACENT STRAKE, ABOUT FR. 93, STBD.		
ABRAHAM BALDWIN	EC2 S-C1	DELTA SB Co. Inc.	16 MAY '42	8	X FEB. '43	BALLASTED	UNKNOWN			WINTER	SHEER & STRINGER PLATES FRS. 90-91	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
CHAMPLAIN ex BELLE ISLE	L6 S-B1	AMERICAN SB Co. CLEVELAND	15 NOV. '42	2	12 FEB. '43	INCOMPLETE	CALM			11°-29°/	SHEER, STRINGER PLATES & HOPPER SIDES, PORT & STBD, FR. 100 (#9 HATCH)	DEFECTIVE BUTT WELDS OF #4 TCH FACING CHANNELS	COMPLETE FRACTURE OF STRENGTH DECK
JOHN FITCH	EC2 S-C1	PERMANENTE METALS #2	28 AUG. '42	5	15 FEB. '43	LOADED 22/10 - 26/5	NORMAL	4		-18°/33°	STRINGER & TWO INBOARD STRAKES, BULWARK, SHEER & STRAKE BELOW, FRS. 81-85 PORT	PROBABLY AT BUTT WELD OF BULWARK RAIL	
HENRY WYNKOOP	EC2 S-C1	DELTA SB Co. Inc.	26 NOV. '42	2	16 FEB. '43	LOADED 24/6 - 27/6	CALM			7°-17°/31°	UPPER DECK FROM E. PORT, FRS 62-69 SHEER & STRAKE BELOW	UNKNOWN	
JAMES BOWIE	EC2 S-C1	TODD-HOUSTON CORP.	27 OCT. '42	3	19 FEB. '43	LOADED 25/10 - 27/9	HEAVY PORT QTR.	9-10		44°/36°	STRINGER, SHEER & STRAKE BELOW, FRS 91-92	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
THOMAS SUMTER	EC2 S-C1	NORTH CAROLINA SB Co.	31 MAY '42	9	24 MAR. '43	LOADED 27/0 - 27/3	HEAVY	8		24°/34°	SHEER & STRINGER PLATES FRS 90-91, 91-92 & 102-103	AT FRS 90-93 CUT IN SHEER-STRAKE FOR ACCOMMODATION LADDER	
THOMAS HOOKER	EC2 S-C1	NEW ENGLAND SB CORP.	13 JULY '42	7	5 MAR. '43	BALLASTED 14/0 - 22/0	HEAVY	7	9 K.	22°/	DECK & SHELL IN WAY OF #3 HATCH	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK. ABANDONED
J. L. M. CURRY	EC2 S-C1	ALABAMA DD&SB Co.	31 JAN. '42	13	7 MAR. '43	BALLASTED 12/10 - 19/10	HEAVY	10	5K.	14°-30°/	DECK & SHELL AT FWD. CORNERS OF #5 HATCH STBD., AFTER CORNERS #3 & #4 HATCH PORT	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK. ABANDONED
STEPHEN C. FOSTER	EC2 S-C1	TODD-HOUSTON CORP.	12 JAN. '43	2	14 MAR. '43	LOADED 23/3 - 26/6	CALM			/30°	DECK AT FWD PORT CORNER #3 HATCH & SHEERSTRAKE, AFT STBD CORNER #3 HATCH FOR	EXACTLY AT HATCH CORS. IN TWO STRAKES	
JOAQUIN MILLER	EC2 S-C1	PERMANENTE METALS #1	22 JULY '42	7	15 MAR. '43	LOADED 25/11 - 26/1	HEAVY	9		30°/34°	DECK AT FWD PORT CORNER #3 HATCH, SHEER & TWO STRAKES BELOW	EXACTLY AT HATCH CORNER	
LEW WALLACE	EC2 S-C1	PERMANENTE METALS #1	21 JULY '42	8	26 MAR. '43	BALLASTED	HEAVY	9		17°-20°/	STRINGER, SHEER & STRAKE BELOW, FRS 91-92 PORT	PROBABLY AT CUT IN SH. LR-STRAKE FOR ACCOM. LADDER	
ESSO MANHATTAN	T2-SE-A1	SUN SB Co.	31 JULY '42	7	29 MAR. '43	BALLASTED 17/6 - 33/6	CALM	2	14 K.	36°-42°/	COMPLETE SECTION OF HULL FRS 55-56 (#6 TANK)	DEFECTIVE BUTT WELD OF @ STRAKE, MAIN DECK.	BROKE IN TWO AT SEA - SALVAGED
CHRISTOPHER GREENUP	EC2 S-C1	OREGON SB CORP.	5 MAR. '43	1	29 MAR. - 2 APR. '43	LOADED	NORMAL			16°M/	SHEER & STRINGER PLATES IN WAY OF HALF ROUND MOULDING	BUTT WELD OF HALF ROUND MOULDING	
WILLIAM L. SMITH	EC2 S-C1	TODD-HOUSTON CORP.	6 JAN. '43	2	3 APR. '43	BALLASTED	HEAVY			SPRING	DECK & SHEERSTRAKE AT FWD. STBD. CORNER OF #3 HATCH	EXACTLY AT HATCH CORNER	
THOMAS JOHNSON	EC2 S-C1	CALIFORNIA SB CORP.	24 OCT. '42	5	14 APR. '43	LOADED 28/6 - 27/6	HEAVY		6-11 K	UNKNOWN	STRINGER & SHEERSTRAKE, FRS. 112-113 STBD.		
BROCKHOLST LIVINGSTON	EC2 S-C1	CALIFORNIA SB CORP.	21 OCT. '42	6	2 MAY '43	BALLASTED 16/0 - 20/0	HEAVY	8	69 R.P.M	SPRING ICELAND AREA	DECK EXCEPT @ STRAKE, BULWARK, SHEER & STRAKE BELOW FRS. 112 - 113.	UNKNOWN	COMPLETE FRACTURE IN STRENGTH DECK
ANDREW MOORE	EC2 S-C1	DELTA SB Co. Inc.	7 SEPT. '42	7	5 MAY '43	BALLASTED	HEAVY	8-10		SPRING	BILGE KEEL & BILGE STRAKES, FRS. 64-68	DEFECTIVE BUTT WELD OF BILGE KEEL	
WILLIAM H. CRAWFORD	EC2 S-C1	TODD-HOUSTON CORP.	5 FEB. '43	3	5 MAY '43	LOADED 24/3 - 28/10	HEAVY	8	66 RPM	AUTUMN AUSTRALIAN AREA	DECK & SHEERSTRAKE AT FWD STBD CORNER & AFTER PORT CORNER #3 HATCH	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK
FREDERIC REMINGTON	EC2 S-C1	PERMANENTE METALS #1	6 DEC. '42	4	5 MAY '43	LOADED 26/11 - 27/10	HEAVY	9		AUTUMN	SHEER & STRINGER PLATES FRS. 90-91	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
MARKAY	TANKER NOT MC	SUN SB & DD Co.			29 JUNE '43	LOADED	HEAVY		16 K.	UNKNOWN	BILGE STRAKES IN WAY OF #3 PORT TANK	DEFECTIVE BUTT WELD OF SHELL PL'TING	
JOHN GORRIE	EC2 S-C1	ST. JOHN'S RIVER SB Co. Inc.	27 MAR. '43	6	13 OCT. '43	BALLASTED	HEAVY	8		43°/	DECK, SHEER & STRAKE BELOW STBD PORT & AFTER STBD CORNER #3 HATCH, SHEER & STRAKE BELOW	FWD STBD CORN. #3 HATCH PROBABLY AT BUTT WELD OF BULWARK	COMPLETE FRACTURE OF STRENGTH DECK
ABRAHAM BALDWIN	EC2 S-C1	DELTA SB Co. Inc.	16 MAY '42	19	13 OCT. '43	BALLASTED 13/4 - 19/6	HEAVY HEAD	7		49°/49°	SHEER, STRINGER & ADJACENT STRAKE ABOUT FR 90 PORT	PROBABLY AT CUT IN SHEERSTRAKE FOR ACCOM. LADDER	
S.M. BABCOCK	EC2 S-C1	OREGON SB CORP.	1 NOV. '42	11	14 OCT. '43	BALLASTED 16 MEAN	HEAVY	10		38°/	DECK FROM VENTILATOR TO GUNWALE, SHEER & STRAKE BELOW, FRS. 113-118 STBD.		
RICHARD J. REISS	L6-S-B1	GREAT LAKES Eng. Wks. RIVER ROUGE	19 SEPT. '42	12	17 OCT. '43	LOADED	HEAVY			AUTUMN	STRINGER & HOPPER SIDE AT FR. 100, PORT	PROBABLY AT CORNER OF ACCESS OPENING	
ROBERT C. STANLEY	L6-S-B1	GREAT LAKES Eng. Wks. RIVER ROUGE	19 JUNE '43	4	10 NOV. '43	LIGHT	HEAVY			AUTUMN	STRINGER & HOPPER SIDE BETWEEN #9 & #10 HATCHES, STBD	PROBABLY IN WELDING OF INSERT @ OF ACCESS OPENING	
JOHN P. GAINES	EC2 S-C1	OREGON SB CORP.	11 JULY '43	4	24 NOV. '43	BALLASTED 13/0 - 19/0	NORMAL HEAD	5-6	9 K. 61 R.P.M.	46°-65°/	COMPLETE CROSS SECTION IN WAY OF FWD. END #3 HATCH	NEAR FWD. CORNERS OF HATCH	BROKE IN TWO AT SEA - ABANDONED
THEODORE SEDGWICK	EC2 S-C1	TODD-HOUSTON CORP.	19 AUG. '42	15	28 NOV. '43	BALLASTED 15/9 - 21/0	HEAVY HEAD	6	4.7 K.	35°/	DECK, SHEER & STRAKE BELOW AT FWD. STBD. CORNER #3 HATCH, DECK FROM HEAT, TO GUNWALE & SHEERSTRAKE FRS. 83-83 PORT	EXACTLY AT HATCH CORNER; PROBABLY VERT. OPENING IN SHEERSTRAKE FRS. 83-83 PORT	DBL.
GEORGE B. SELDEN	EC2 S-C1	PERMANENTE METALS #2	4 NOV. '42	12	29 NOV. '43	BALLASTED 11'0 - 20/0	HEAVY	9-10		AUTUMN	STRINGER, SHEER & STRAKE BELOW FRS. 102-103, PORT		
LAMBERT CADWALADER	EC2 S-C1	TODD-HOUSTON CORP.	16 NOV. '42	12	X DEC. '43	LOADED	UNKNOWN			WINTER	STRINGER & SHEERSTRAKES FRS. 91-92, PORT	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
LAURA KEENE	EC2 S-C1	KAISER Co. Inc. VANCOUVER	1 FEB. '43	10	11 DEC. '43	BALLASTED 11/0 - 20/0	NORMAL	5	9 7½ K.	AUTUMN	DECK, BULWARK, SHEER & STRAKE BELOW AT FWD. STBD CORNER #3 HATCH	PROBABLY AT HATCH CORNER	
PHINEAS BANNING	EC2 S-C1	CALIFORNIA SB CORP.	9 FEB. '43	10	11 DEC. '43	BALLASTED 11/6 - 21/7	HEAVY	8-10	2.5-4.0 K	60°/64°	DECK, BULWARK & SHEERSTRAKE AT TWO STBD. CORNERS & AFT PORT CORNER #2 HATCH	EXACTLY AT HATCH CORNERS	COMPLETE FRACTURE OF STRENGTH DECK
CHIEF WASHAKIE	EC2 S-C1	OREGON SB CORP.	24 DEC. '42	11	11 DEC. '43	BALLASTED 11/6 - 19/6	HEAVY BOW	10	45 R.P.M.	29°/42°	DECK & SHEERSTRAKE AT FWD STBD (AFT PORT CORNERS #3 HATCH), STRINGER & 2 INBOARD STRAKES, SHEER & STRAKE BELOW FRS 85-86 PORT	EXACTLY AT HATCH CORNERS; UNKNOWN	COMPLETE FRACTURE OF STRENGTH DECK
VALERY CHKALOV	EC2 S-C1	PERMANENTE METALS #2	4 APR. '43	7	11 DEC. '43	BALLASTED	HEAVY	11		29°-33°/	COMPLETE CROSS SECTION IN WAY OF FWD. END #3 HATCH.	EXACTLY AT HATCH CORNERS	BROKE IN TWO AT SEA - SALVAGED.
HAT CREEK	T2-SE-A1	ALABAMA DD & SB Co.	30 APR. '43	7	11 DEC. '43	LOADED 29/6 - 32/6	HEAVY	6	9 K. 50 RPM	32°/48°	BILGE STRAKES IN WAY OF #3 PORT TANK FOR 20'-0"		
JOAQUIN MILLER	EC2-S-C1	PERMANENTE METALS #1	22 JULY '42	16	15 DEC. '43	LOADED 25/3 - 28/6	CALM			AUTUMN	STRINGER, SHEER & STRAKE BELOW, FRS. 90-91 PORT	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
ASKOLD	EC2-S-C1	OREGON SB CORP.	24 JUNE '43	5	15 DEC. '43	UNKNOWN	UNKNOWN			AUTUMN	DECK, STRINGER & STRAKE BELOW, FROM #2 HATCH	PROBABLY AT HATCH CORNER	
JAMES GORDON BENNETT	EC2-S-C1	CALIFORNIA SB CORP.	13 SEPT. '42	15	18 DEC. '43	UNKNOWN	UNKNOWN			26°-42°/	STRINGER, SHEER & STRAKE BELOW, FRS. 43-44		
HAT CREEK	T2-SE-B1	ALABAMA DD & SB Co.	30 APR. '43	7	13 DEC. '43	LIGHT	UNKNOWN			AUTUMN	SHEER STRINGER & STRAKE BELOW IN WAY OF #6 TANK, 10 STRAKES OF BOTTOM SHELL PL'TING & 2 STRAKES OF SIDE SHELL PL'TING	UNKNOWN; PROBABLY IN BUTT WELD OF SHELL PLATES	

POTENTIALLY SERIOUS STRUCTURAL FRACTURES

NAME OF VESSEL	TYPE	YARD	LAUNCHING DATE	MONTHS AFLOAT	CASUALTY DATE	LOADING & DRAFTS	SEA CONDITION & DIRECTION	WIND FORCE	SHIP'S SPEED IN KNOTS	TEMPERATURE AIR/WATER	LOCATION OF FRACTURE	ORIGIN OF FRACTURE	REMARKS
CHARLES CROCKER	EC2-S-C1	CALIFORNIA SB CORP.	11 MAY '43	7	21 DEC '43	LOADED 23/10-24/6	NORMAL	4	9½ K.	74°/75°	STRINGER & SHEERSTRAKE FRS. 110-112, PORT		
WALTER HINES PAGE	EC2-S-C1	NORTH CAROLINA SB Co.	27 APR '43	7	23 DEC. '43	BALLASTED	HEAVY			33°/54°	DECK & SHEERSTRAKE AT FWD. STBD. CORNER #3 HATCH	PROBABLY AT HATCH CORNER	
ALEXANDER NEVSKY	EC2-S-C1	OREGON SB Corp	29 MAR '43	8	24 DEC '43	BALLASTED	HEAVY	9	5-6 K. 65 RPM	WINTER	IN VICINITY OF #2 HATCH IN DECK & SHELL		
WILLIAM BLACK YATES	EC2-S-C1	SOUTHEASTERN SB CORP.	27 SEPT '43	3	28 DEC '43	BALLASTED	HEAVY	7-8		34°/35°	STRINGER, SHEER & BULWARK FRS. 101-103 PORT	PROBABLY AT FWD. CORNER OF FREEING PORT	
ABIEL FOSTER	EC2-S-C1	CALIFORNIA SB CORP.	22 MAR '42	21	29 DEC '43	BALLASTED 11/8-21/0	HEAVY	7-8	5 K.	42°/50°	DECK & SHEERSTRAKE AT FWD STBD CORNER; DECK AT FWD. PORT CORNER #3 HATCH	EXACTLY AT HATCH CORNERS	COMPLETE FRACTURE OF STRENGTH DECK
GEORGE CHAMBERLIN	EC2-S-C1	OREGON SB Corp.	14 AUG '42	16	29 DEC '43	BALLASTED 11/6-21/0	HEAVY	11-12		40°/ .	DECK, BULWARK, SHEER & STRAKE BELOW AT FWD. STBD CORNER #4 HATCH	PROBABLY AT HATCH CORNER	
JOHN VINING	EC2-S-C1	DELTA SB Co. Inc.	23 NOV. '42	13	2 JAN. '44	LOADED 24/0-25/2	CALM	1		13°/38°	STRINGER, BULWARK, SHEER & STRAKE BELOW FRS. 109-110 PORT		
SEA BASS	C3-S-A2	WESTERN PIPE & STEEL Co.	2 AUG. '42	17	5 JAN. '44	LOADED 24/10-29/8	HEAVY	6		55°/52°	DECK & SHEERSTRAKE PORT; DECK STBD. AT AFTER CORNERS #3 HATCH.	HATCH CORNERS	COMPLETE FRACTURE OF STRENGTH DECK
EMILIAN PUGACHEV	EC2-S-C1	OREGON SB Corp.	13 APR. '43	8	5th JAN. '44	BALLASTED	UNKNOWN			WINTER. NORTH PACIFIC	DECK, SHEERSTRAKE & STRAKE BELOW AT FWD. PORT CORNER & AFT. STBD. CORNER #4 HATCH.		COMPLETE FRACTURE OF STRENGTH DECK
ROBERT NEWELL	EC2-S-C1	OREGON SB Corp.	2 MAY '43	8	6 JAN. '44	LOADED 21/4-25/2	HEAVY 2 PTS. ON PORT QTR.	7	10 K.	WINTER	DECK FROM GUNWALE TO WITHIN 2 FEET OF #3 HATCH FRS. 75-76, STBD.	PROBABLY IN BUTT WELD OF DECK	
JOSEPH R. LAMAR	EC2-S-C1	J.A. JONES CONST. BRUNSWICK	29 APR. '43	8	9 JAN. '44	BALLASTED 13/0-21/0	HEAVY	8-10	7 K.	80°/68°	DECK FROM & TO GUNWALE, FWD. #4 HATCH		
JOSEPH SMITH	EC2-S-C1	PERMANENTE METALS #2	22 MAY '43	7	9 JAN. '44	BALLASTED 7/0-21/0	HEAVY CROSS	6-9	7 K.	34°/50°	DECK & SHELL NEAR FWD END #4 HATCH; TWO CORNERS #3 HATCH		COMPLETE FRACTURE OF STRENGTH DECK & ABANDONED
THEODORE PARKER	EC2-S-C1	CALIFORNIA SB CORP.	24 FEB. '43	10	9 JAN. '44	BALLASTED 11/0-20/0	HEAVY	6	6 K.	44°/56°	DECK AT FWD PORT CORNER & ONE STRAKE AT AFTER STBD. CORNER #3 HATCH.	EXACTLY AT HATCH CORNER	
WILLIAM L. MARCY	EC2-S-C1	CALIFORNIA SB CORP.	28 DEC. '42	12	12 JAN. '44	BALLASTED 12/5-20/3	HEAVY HEAD	8-9	5 K.	38°/51°	DECK, SHEER & STRAKE BELOW AT AFTER PORT CORNER DECK AT FWD. STBD. CORNER #3 HATCH	EXACTLY AT HATCH CORNERS	COMPLETE FRACTURE OF STRENGTH DECK
ROGER GRISWOLD	EC2-S-C1	DELTA SB Co. Inc.	1 MAR. '43	10	12 JAN. '44	BALLASTED 12/0-21/6	HEAVY HEAD	8	9 K.	38°/58°	DECK, BULWARK, SHEER & STRAKE BELOW AT FWD. STBD. CORNER #3 HATCH.	EXACTLY AT HATCH CORNER	
JOSEPH N. NICOLLET	EC2-S-C1	DELTA SB Co. Inc.	24 MAY '43	7	14-16 & 27 JAN. '44	LOADED 25/2-28/1	HEAVY	10	½ SPEED	32°/	DECK FROM VENTILATOR TO GUNWALE, SHEER TO 2nd DECK FRS. 112-113		
ESSO WASHINGTON	T2-SE-A1	SUN SB & DD Co.	10 NOV '42	12	16 JAN. '44	LOADED	HEAVY	5-8	13 K.	WINTER.	THREE BILGE STRAKES AT FWD. END #5 TANK, STBD.	PROBABLY BUTT WELD OF SHELL	
JEFFERSON DAVIS	EC2-S-C1	ALABAMA SB & DD Co.	12 JULY '42	18	16 JAN. '44	LOADED 24/0-25/9	HEAVY	8-9		41°/42°	STRINGER & TWO INBOARD STRAKES, FRS. 83-84, STBD		
LORENZO DEZAVALA	EC2-S-C1	TODD-HOUSTON CORP.	29 MAY '43	7	20th JAN. '44	BALLASTED 13/6-20/6	HEAVY			54°/47°	DECK, SHEER, & STRAKE BELOW AT FWD. STBD. CORNER #4 HATCH	PROBABLY AT HATCH CORNER	
GEORGE GALE	EC2-S-C1	DELTA SB Co. Inc.	15 JULY '42	18	21st JAN. '44	BALLASTED	HEAVY	6		42°/50°	STRINGER, SHEER & STRAKE BELOW, PORT SIDE NEAR AMIDSHIPS.		
SAMUEL DEXTER	EC2-S-C1	DELTA SB Co. Inc.	29 MAR '43	9	21 JAN. '44	BALLASTED 9/6-21/0	HEAVY 3 PTS. ON STBD. BOW	8	47 RPM	40°/48°	DECK & SHEERSTRAKE AT FWD. CORNERS #3 HATCH & FWD STBD. CORNER #4 HATCH.	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK ABANDONED
JANE LONG	EC2-S-C1	TODD-HOUSTON CORP.	14 MAY '43	8	22 JAN. '44	BALLASTED 13/6-21/0	HEAVY		6 K.	37°/49°/	DECK, SHEER & STRAKE BELOW FROM PORT SIDE #4 HATCH.		
JAMES GORDON BENNETT	EC2-S-C1	CALIFORNIA SB CORP.	13 SEPT '42	16	22 JAN. '44	BALLASTED 11/1-18/3	HEAVY	7	10 K.	WINTER	DECK TO VENTILATOR, BULWARK & SHEERSTRAKE, FRS 83-84 STBD		
JULIEN POYDRAS	EC2-S-C1	DELTA SB Co. Inc.	17 MAY '43	8	24 JAN. '44	LOADED 23/6-26/10	HEAVY	5-7		47°/54°	DECK AT FWD. PORT CORNER #3 HATCH	EXACTLY AT HATCH CORNER	
GEORGE A. CUSTER	EC2-S-C1	CALIFORNIA SB CORP.	23 SEPT '42	16	25 JAN. '44	BALLASTED 14/1-20/1	HEAVY HEAD	8-6	8 K.	44°/47°	DECK AT FWD. PORT CORNERS #3 HATCH.	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK
RICHARD J. CLEVELAND	T2-ET1-S-C3	CALIFORNIA SB. CORP.	15 SEPT '43	4	28 JAN. '44	LOADED 25/0-28/4	HEAVY 2 PTS. ON STBD BOW	8		24°/34°	DECK FROM VENTILATOR TO GUNWALE, SHEER & STRAKE BELOW, FR. 112 STBD.	PROBABLY AT VENT OPENING IN DECK	
DEKABRIST	EC2-S-C1	OREGON SB Corp	27 FEB. '43	11	29 JAN. '44	LOADED	HEAVY			WINTER	DECK & SHELL TO TWEEN DECK AT FWD PORT CORNER #3 HATCH.	PROBABLY AT HATCH CORNER	
ABRAHAM BALDWIN	EC2-S-C1	DELTA SB Co. Inc.	16 MAY '42	20	29 JAN. '44	BALLASTED	HEAVY			WINTER	DECK INBOARD 16', SHELL 14' ABOUT 5' AFTER #3 HATCH		
WILLIAM H. PRESCOTT	EC2-S-C1	CALIFORNIA SB CORP.	21 JULY '42	18	1 FEB. '44	BALLASTED 12/10-21/4	HEAVY HEAD	8-10	4-5 K.	52°/50°	DECK & SHELL IN TWEEN DECK AT FWD PORT & AFTER STBD. CORNERS #3 HATCH.	PROBABLY AT HATCH CORNER	COMPLETE FRACTURE OF STRENGTH DECK
AMELIA EARHART	EC2-S-C1	TODD-HOUSTON CORP.	18 DEC. '42	13	2 FEB. '44	BALLASTED 11/10-21/2	HEAVY	9	5.2 K.	50°/49°	DECK AT FWD. STBD. CORNER #3 HATCH; DECK FROM VENT TO GUNWALE, FR. 83 PORT.	PROBABLY AT HATCH CORNER	
JOHN L. SULLIVAN	EC2-S-C1	PERMANENTE METALS #2	26 MAY '43	8	2 FEB. '44	BALLASTED 13/3-19/8	HEAVY	9-11	3 K.	50°/54°	DECK & SHELL TO TWEEN DECK AT FWD STBD. CORNER #3 HATCH.	PROBABLY AT HATCH CORNER	
SAMUEL ADAMS	EC2-S-C1	CALIFORNIA SB CORP.	31 JAN. '42	24	3 FEB. '44	BALLASTED 8/0-15/0	CALM	2		32°/34°	STRINGER, BULWARK & SHEER FRS. 111-112, STBD.		
SAM HOUSTON II	EC2-S-C1	TODD-HOUSTON CORP.	30 JUNE '43	7	4 FEB. '44	LOADED 26/7-25/11	HEAVY PORT BEAM	4	63 RPM	38°/42°	DECK & SHELL TO TWEEN DECK AT FWD STBD. END #2 HATCH & AT GANGWAY	EXACTLY AT HATCH CORNER, UNKNOWN	
VERNON L. KELLOGG	EC2-S-C1	CALIFORNIA SB CORP.	15 JULY '43	6	5 FEB. '44	LOADED 26/0-29/0	HEAVY	7-8	8.5 K.	52°/63°	DECK INBOARD FROM GUNWALE FOR 8'-0" & SHEERSTRAKE AW 8'-0"		
CYRUS H. McCORMACK	EC2-S-C1	PERMANENTE METALS #2	2 OCT. '42	16	12 FEB. '44	BALLASTED 8/4-18/4	HEAVY 3 PTS. ON STBD. BOW	8	5 7/8 K.	38°/54°	STRINGER & SHEERSTRAKE FRS. 90-91 STBD.	CUT IN SHEERSTRAKE FOR ACCOMMODATION LADDER	
CHAMP CLARK	EC2-S-C1	TODD-HOUSTON CORP.	30 DEC. '42	13	28 FEB. '44	BALLASTED	HEAVY	6	9 K.	28°/	DECK & SHELL TO TWEEN DECK AT FWD. PORT CORNER #4 HATCH	EXACTLY AT HATCH CORNER	
CHARLES TREADWELL	M3-S-A1	PACIFIC-BRIDGE Co.	7 NOV. '42	15	X MAR '44	BALLASTED	HEAVY			WINTER.	STRINGER & SHEERSTRAKE STBD.		
GEORGE P. GARRISON	EC2-S-C1	TODD-HOUSTON CORP.	12 JULY '43	7	2 MAR '44	LOADED 26/0-25/8	HEAVY	11-12	4.44 K.	36°/45°	STRINGER & TWO INBOARD STRAKES AND SHEER FR. 134 PORT.		
McCLELLAN CREEK	T2-SE-A1	ALABAMA DD & SB Co.	4 APR '43	10	2 MAR '44	BALLASTED 4/7-15/11	NORMAL	4		14°/38°	DECK FROM CARGO HATCH TO GUNWALE, SHEER & TWO STRAKES BELOW, FRS 53-54 STBD.		
ELISHA GRAVES OTIS	EC2-S-C1	PERMANENTE METALS #2	5 MAY '43	9	3 MAR '44	BALLASTED	HEAVY			WINTER.	DECK & SHELL TO TWEEN DECK AFT. PORT & DECK FOR 10'-0" AT FWD. STBD. CORNER #3 HATCH	PROBABLY AT HATCH CORNER	
JANE A. DELANO	EC2-S-C1	PERMANENTE METALS #2	9 MAR. '43	11	4 MAR. '44	LOADED 20/5-27/9	HEAVY FWD. PORT BEAM	6-8	6 K.	20°/40°	DECK FROM & TO GUNWALE, SHEER & STRAKE BELOW. FRS 83-84 STBD.		
JOEL R. POINSETT	EC2-S-C1	TODD-HOUSTON CORP.	19 FEB. '43	12	4 MAR '44	BALLASTED 13/0-21/5	HEAVY 3 PTS ON STBD. BOW	8-12	5 K. 60 R.P.M	20°/40°	COMPLETE CROSS SECTION BETWEEN #3 HATCH & DECK HOUSE		BROKE IN TWO STERN HALF SALVAGED
JAMES IREDELL	EC2-S-C1	NORTH CAROLINA SB Co.	29 NOV. '42	15	4 MAR '44	LOADED	HEAVY QUARTER			WINTER.	DECK AT AFTER PORT CORNER #2 HATCH AND AT DECK FROM #4 HATCH, FRS 62-63 PORT.	EXACTLY AT HATCH CORNER; UNKNOWN	
WILLIAM M. MEREDITH	EC2-S-C1	OREGON SB Corp.	5 FEB. '43	13	5 MAR '44	LOADED 19/4-24/4	CALM			34°/35°	STRINGER SHEER & STRAKE BELOW, FRS 137-138 PORT	BUTT WELD OF HALF ROUND GUNWALE MOULDING	
CHARLES CROCKER	EC2-S-C1	CALIFORNIA SB CORP.	11 MAY '43	10	15 MAR '44	LOADED 28/11½-28/11½	NORMAL	4	7½ K.	50°/70°	DECK & SHEERSTRAKE AT FWD. STBD. CORNER #3 HATCH	EXACTLY AT HATCH CORNER	
WHITE OAK	T2-SE-A1	KAISER Co. Inc. SWAN ISLAND	25 SEPT '43	5	22 MAR '44	UNKNOWN	UNKNOWN			SPRING	BILGE & BOTTOM SHELL FOR ABOUT 14' FR. 61 STBD.	DEFECTIVE WELDING IN ADJACENT SHELL BUTTS.	
SUCHAN	EC2-S-C1	CALIFORNIA SB CORP.	2 MAY '43	12	16 MAY '44	UNKNOWN	UNKNOWN			SPRING	SHEAR & STRINGER PLATES FR. III STBD.		
JOHN P. ALTGELD	T-ET1-S-C3	CALIFORNIA SB CORP.	18 OCT. '43	11	9 OCT. '44	LOADED 26/0-28/0	HEAVY	9		45°/56°	SHEER, STRINGER & STRAKE INBOARD, FRS. 113-114 STBD.	END OF SLOTTED FREEING PORT IN BULWARK	
FERDINANDO GORGES	EC2-S-C1	NEW ENGLAND SB CORP.	12 AUG. '43	16	16 DEC. '44	LOADED 27/1-30/5	NORMAL BEAM	5	7 K.	39°, 47°/48°, 52°	DECK, SHEER, & STRAKE BELOW, FRS 81-82 PORT.	DEFECTIVE BUTT WELD OF STRINGER PLATES	
WARRIOR	C2-S-E1	GULF SB CORP	14 MAR '43	22	27 JAN. '45	LOADED 26/8-27/0	NORMAL 4 PORT QTR.	4	14 K.	32°/47°	ON TWO THIRDS WIDTH OF TRANSOM PLATE AT PORT SIDE, STARTED FROM AFT END OF SHELL PLATE	BUTT WELDS OF BULWARK RAIL IN VICINITY OF STRINGER; DECK DOUBLER.	COMPLETE FRACTURE OF STRENGTH DECK
LEBANON	C1-M-AV1	WALTER BUTLER SB Inc.	14 OCT. '44	2	9 JAN '45	LIGHT 11'8-14'0	CALM BAY SCREEN			-16°/32°	DECK FROM COAMING #3 HATCH TO RIVET IN GUNWALE, FRS. 81-82, STBD.	PROBABLY IN HATCH COAMING	

DESCRIPTION OF VESSEL

1 Oct., 1944 (Date)

NAME	OFFICIAL NO.	TYPE (Dry Cargo, Passenger, etc.)	M.C. DESIGN
ABIEL FOSTER (1)	241606	Dry Cargo Vessel	EC2-S-C1
BUILDER		BUILDER'S HULL NO.	DATE COMPLETED
California S.B. Corp.		#15	16 May, 1942
OWNER		OPERATOR	
War Shipping Administration		Matson Navigation Company	

EXTENT OF WELDING

yes	SIDE SHELL SEAMS					yes	DECK SEAMS
yes	SIDE SHELL BUTTS	yes	BOTTOM SEAMS	yes	INNER BOTTOM SEAMS	yes	DECK BUTTS
no	FRAMES TO SIDE SHELL	yes	BOTTOM BUTTS	yes	INNER BOTTOM BUTTS	yes	BEAMS TO DECK
yes	BULKHEADS	yes	FLOORS TO SHELL	yes	FLOORS TO INNER BOTTOM	yes	DECK TO SHELL

CIRCUMSTANCES SURROUNDING FAILURE

(Attach all available details of ship's loading)

DATE OF FAILURE	TIME	SHIP'S LOCATION		
29 Dec., 1943	1240	Lat. 60°-37' N, long. 21°-99' W, enroute from Milford Haven, Wales to United States.		
SHIP'S SPEED	COURSE		DRAFT FWD.	DRAFT AFT
5 knots	--		11'-9"	21'-0"
SEA CONDITION	WEATHER	DIRECTION OF WAVES WITH RESPECT TO SHIP		
Mountainous	Heavy	Head sea		
WIND FORCE	WIND DIRECTION	AIR TEMPERATURE	WATER TEMPERATURE	
7-8	WNW-Head	42°	50°	

DESCRIPTION OF FAILURE

(Include sketch of fracture showing starting point and relative location of welds and other structural features)

APPARENT STARTING POINT

The fractures started in the upper deck plating exactly at the forward corners of #3 hatch.

GENERAL HISTORY AND DESCRIPTION OF FAILURE, INCLUDING KNOWN CONTRIBUTORY FACTORS:

The vessel departed from Plymouth, England on 17 Dec., 1943 in ballast and after two stops, left Milford Haven, Wales, in convoy on 23 Dec., 1943. At 1240 on 29 Dec., 1943, rolling and pitching heavily, the vessel pounded on a mountainous sea and cracked her deck and shell plating. Fracture extended from ford. stbd. corner #3 hatch through doubler near frame 73, to ship's side and downward for about 14 feet ending 2 feet in "H" strake. Another crack started at ford. port corner #3 hatch ran horizontally across deck near frame 73, and stopped at gunwale. Both fractures extended upward into coaming and downward through longitudinal hatch side girders. After corners #3 hatch coaming, stbd. and port fractured. Both ford. corners #4 hatch fractured extending about 6" into deck plating. Bulwark rail bar abreast #3 hatch fractured port side. Stanchions at frd. end of midship house, port and stbd. cracked.

Vessel broke convoy and returned to Greenock, Scotland.

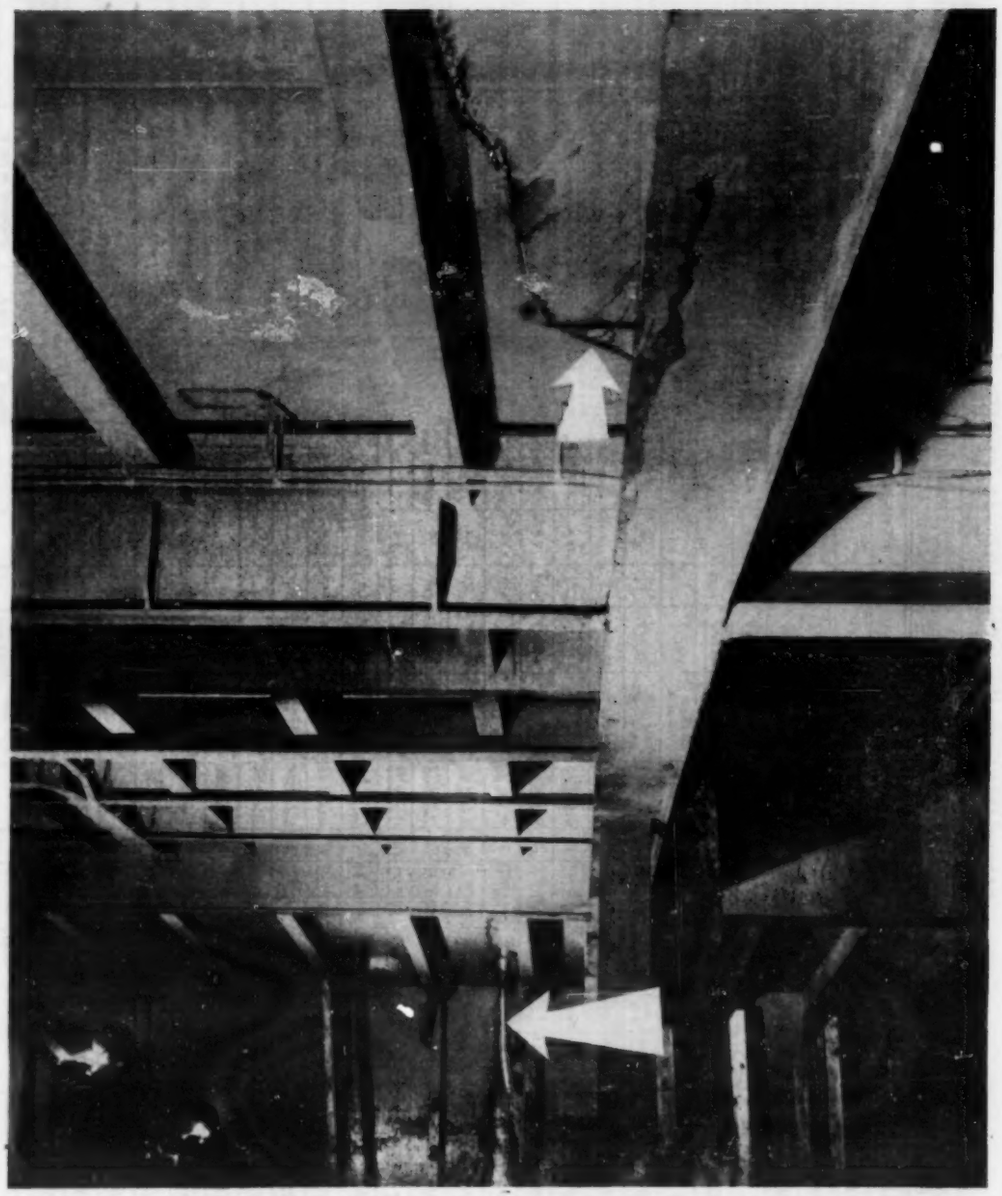
CLASSIFICATION OF FAILURE: cracked deck

DISPOSITION OF VESSEL

(Repaired, lost, etc.)

Vessel was repaired at Greenock, Scotland prior to March, 1944

Distribution of Weights	Loading at Time of Failure, Long Tons
Lightship	3670
Crew, passengers and stores	30
Fuel oil, settling tanks	100
Deep tank No. 3	569
Fresh water, potable water tank	50
Reserve feed	134
Forepeak	138
After peak	152
Inner bottom No. 2	100
No. 3	100
No. 5	100
No. 6	100
Ballast in holds No. 1 Deep tank No. 1	228
No. 2	424
hold No. 2	300
No. 3	300
No. 4	400
No. 5	494
Displacement	7289



"Abiel Foster." View from Port Side Looking to Starboard, Showing Forward Port Corner of No. 3 Hatch on Upper Deck and Starboard Shell Plating

Displacement	7280

DESCRIPTION OF VESSEL — 1 Oct. 1944 (Date)

NAME	OFFICIAL NO.	TYPE (Dry Cargo, Passenger, etc.)	M.C. DESIGN
BROCKHOLST LIVINGSTON (1)	242456	Dry Cargo Vessel	EC2-S-C1
BUILDER	BUILDER'S HULL NO.		DATE COMPLETED
California S.B. Corp.	83		7 Nov., 1942
OWNER	OPERATOR		
War Shipping Administration	A. H. Bull Steamship Co.		

EXTENT OF WELDING

yes	SIDE SHELL SEAMS					yes	DECK SEAMS
yes	SIDE SHELL BUTTS	yes	BOTTOM SEAMS	yes	INNER BOTTOM SEAMS	yes	DECK BUTTS
no	FRAMES TO SIDE SHELL	yes	BOTTOM BUTTS	yes	INNER BOTTOM BUTTS	yes	BEAMS TO DECK
yes	BULKHEADS	yes	FLOORS TO SHELL	yes	FLOORS TO INNER BOTTOM	yes	DECK TO SHELL

CIRCUMSTANCES SURROUNDING FAILURE
(Attach all available details of ship's loading)

DATE OF FAILURE	TIME	SHIP'S LOCATION		
2 May, 1943	0325	In Iceland area, en route from Liverpool, England to New York, N. Y.		
SHIP'S SPEED	COURSE		DRAFT FWD.	DRAFT AFT
95 r.p.m.	250°		14'-0"	20'-0"
SEA CONDITION	WEATHER	DIRECTION OF WAVES WITH RESPECT TO SHIP		
Rough	heavy	head sea		
WIND FORCE	WIND DIRECTION	AIR TEMPERATURE	WATER TEMPERATURE	
8	S.W. gale	----	----	

DESCRIPTION OF FAILURE
(Include sketch of fracture showing starting point and relative location of welds and other structural features)

APPARENT STARTING POINT

Unknown.

GENERAL HISTORY AND DESCRIPTION OF FAILURE, INCLUDING KNOWN CONTRIBUTORY FACTORS:

At 0325 on 2 May, 1943, vessel encountered a particularly high sea and pounded heavily, cracking the shell plates on both sides. Fractures occurred, port and starboard, forward of #4 hatch and extended from the gunwale inboard to a point just outboard of "A" strake seam. The shell plating fractured upward through the bulwark rail bulb angles, downward to third strake on side shell and through second deck stringers into "D" strake.

There were approximately seventeen other failures of local character; one in superstructure on upper deck, about six around #4 hatch, two in #3 hatch, one in #2 hatch, three in bulwark rail cap bars, one in boat deck curtain plate, one in tank top and two in corners of accommodation ladder.

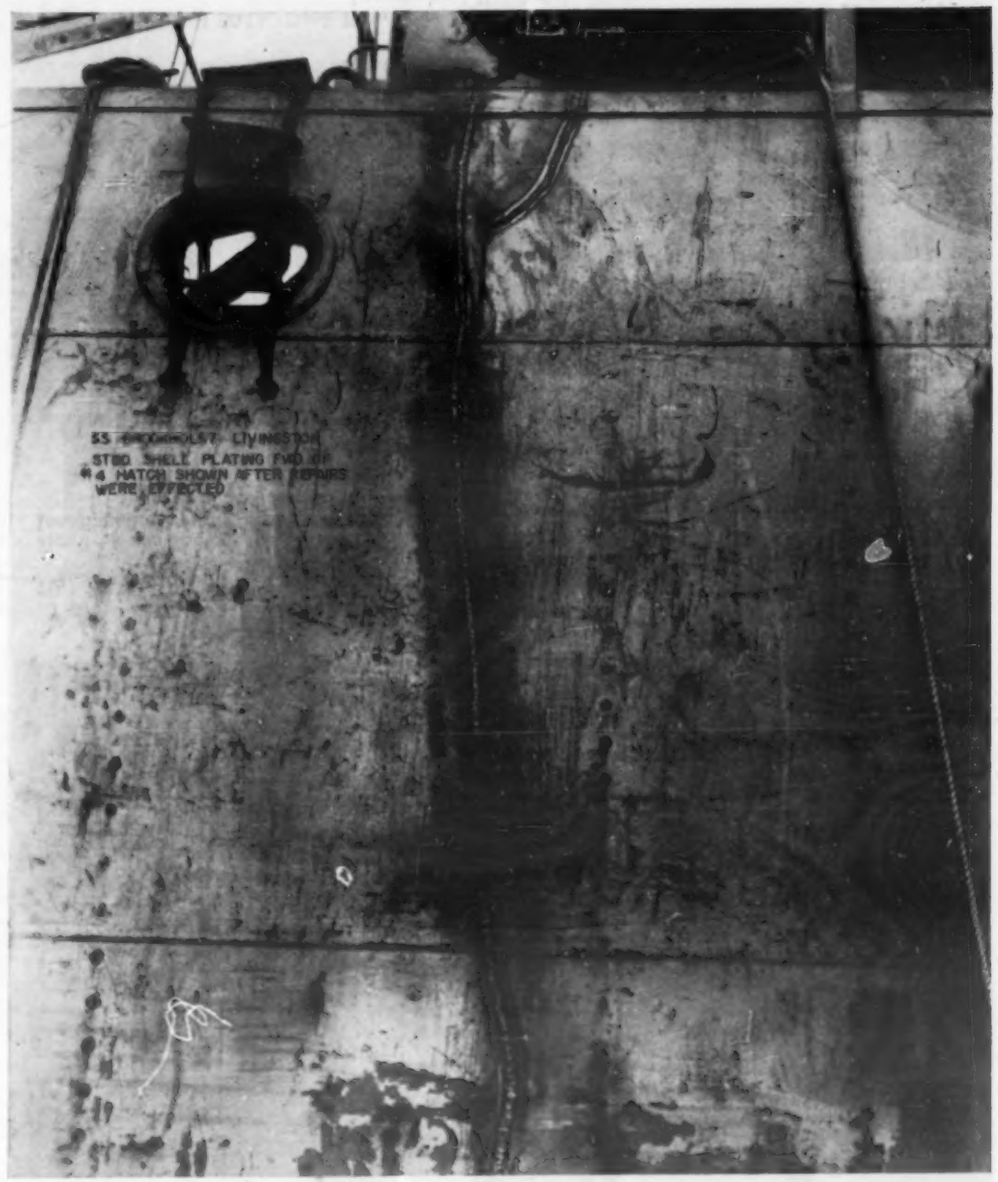
CLASSIFICATION OF FAILURE: cracked deck

DISPOSITION OF VESSEL
(Repaired, lost, etc.)

Vessel was temporarily repaired at Iceland with repairs completed at Brooklyn, N. Y. on 24 June, 1943

SIGNED (Name and Title) | DISTRICT: See reverse side for loading details.

Distribution of Weights	Loading at Time of Failure Long Tons	Distribution of Weights	Loading at Time of Failure Long Tons
Lightship	3670	Salt water ballast	
Crew, passengers and stores	100	Deep tank No. 2	212
Ammunition	40	No. 3	762
Armament	260	Ballast in holds No. 2	500
Fuel oil, settling tanks	100	No. 3	100
Inner bottom No. 3	200	No. 4	500
No. 5	200	No. 5	400
No. 6	200	Additional fixed ballast	
Fresh water, forepeak	145	Bilge No. 3	285
After peak	152	No. 4	285
			8111



S.S. "Brockholst Livingston." Starboard Shell Plating Foward of No. 4 Hatch Shown After Repairs Were Effected

DESCRIPTION OF VESSEL — 1 Oct, 1944 (Date)

NAME: CHAMPLAIN ex BELLE ISLE	OFFICIAL NO.: 243612	TYPE (Dry Cargo, Passenger, etc.): Dry Cargo Vessel	M.C. DESIGN: L6-S-A1
BUILDER: American S.B. Co., Cleveland		BUILDER'S HULL NO.: 1009	DATE COMPLETED: 23 June, 1943
OWNER: Cleveland Cliffs S.S. Co.		OPERATOR: Cleveland Cliffs S.S.Co.	

EXTENT OF WELDING

no	SIDE SHELL SEAMS					yes	DECK SEAMS
yes	SIDE SHELL BUTTS	yes	BOTTOM SEAMS	yes	INNER BOTTOM SEAMS	yes	DECK BUTTS
no	FRAMES TO SIDE SHELL	yes	BOTTOM BUTTS	yes	INNER BOTTOM BUTTS	yes	BEAMS TO DECK
yes	BULKHEADS	yes	FLOORS TO SHELL	yes	FLOORS TO INNER BOTTOM	yes	DECK TO SHELL

CIRCUMSTANCES SURROUNDING FAILURE
(Attach all available details of ship's loading)

DATE OF FAILURE: 12 Feb., 1943	TIME: 1140	SHIP'S LOCATION: Afloat under construction at Cleveland, Ohio		
SHIP'S SPEED: Tied up at dock	COURSE: ----		DRAFT FWD: ---	DRAFT AFT: ---
SEA CONDITION: Calm	WEATHER: ----	DIRECTION OF WAVES WITH RESPECT TO SHIP: ----		
WIND FORCE: ----	WIND DIRECTION: ----	AIR TEMPERATURE: 11°-39°-24 hr. range	WATER TEMPERATURE: ----	

DESCRIPTION OF FAILURE
(Include sketch of fracture showing starting point and relative location of welds and other structural features)

APPARENT STARTING POINT:

Fractures started near the inboard edges of the stringer plates, port and starboard, in faulty butt welds of facing channel adjacent to the hatch near frame 100.

GENERAL HISTORY AND DESCRIPTION OF FAILURE, INCLUDING KNOWN CONTRIBUTORY FACTORS:

The vessel was undergoing test for tightness of peak tanks when fractures occurred in the spar deck breaking the joint between two sections of the facing channel and severing the hatch coaming, deck stringer, sheer strake and extended for 10' down hopper side in way of #9 hatch, frame 100, port and starboard.

The fracture ended in rivet holes in the lower seam of the sheer strake. Eight riveted longitudinals on shell and six of the eight intermittently welded longitudinals on hopper side did not part in way of plate fracture.

CLASSIFICATION OF FAILURE: cracked deck.

DISPOSITION OF VESSEL
(Repaired, lost, etc.)

Repairs were complete on 3 June, 1943 at Cleveland, Ohio

SIGNED (Name and Title): DISTRICT: See reverse side for loading details.

Distribution of Weights	Loading at Time of Failure Long Tons	Distribution of Weights	Loading at Time of Failure Long Tons
Lightship	4505	Tank No. 5	174
Forepeak tank	646	No. 6	6
After peak tank	72	No. 7	787
Tank No. 1	8	No. 8	801
No. 2	5		
No. 4	6	Displacement	7010

On the basis of the loading shown to the left, bending moment calculations were made. The calculated stress made at the point of fracture while vessel was lying afloat in still water was 10,864 lb./in.²

Fig. 1

Fig. 2

Fig. 1—View of S.S. "Champlain (ex Belle Isle)" Showing Location of Vessel When Casualty Occurred

Fig. 2—Good Photograph of Fracture Showing Starting Point in Weld of Hatch Side Channel Girder. Identification Marks Locating Fracture Would Have Improved This Photograph. Note—Visible Herringbone Pattern in Deck Plate (Covered with Snow)—Port Side Shown

Fig. 3—Fractured 50-Lb. Deck Plate from Fig. 2 Showing Poorly Fused Weld in Upper Flange of Longitudinal Hatch Side Girder

and riveted vessels on the basis of standard calculations or empirical formulas was next questioned. It was suspected that the stress distribution in the over-all structure might seriously be altered by the method of fabrication. Full-scale tests in still water were made on five ships. Strain measurements made in different conditions of loading indicated no difference in behavior which could be attributed to the method of attachment.

Advantage was taken of the bending tests to make a study of several construction and design features and additional data were obtained on these items.

This exhibit is divided into three parts. Each part includes the results of a particular phase of the general hull strength studies.

Part A. Calculations comparing the over-all strength of various vessels.

Part B. Data on over-all hull girder strength obtained by tests in still water.

Part C. Data on stress concentrations obtained during full-scale tests in still water.

Part A. Calculations Comparing the Over-all Strength of Various Vessels

Calculations were made for the Liberty ships and the T2-SE-A1 tankers under the two principal standard conditions, i.e., lightship and full load with homogeneous cargo distributed in proportion to the bale capacity of the holds. In addition, calculations were made on assumed condition of hogging and sagging load which, in the case of the tankers, was the worst obtainable with the ship's tanks using salt water ballast and, in the case of the cargo vessel, was the worst which could reasonably be expected under a condition of careless loading. There is little likelihood that Nos. 1 and 5 holds would be filled with dense cargo and the calculations for the hogging condition therefore assured Nos. 2 and 5 holds to be filled as shown on chart attached hereto. Since the Federal Shipbuilding and Drydock Co. had already prepared an extensive study of the longitudinal strength of the "Enders M. Voorhees," which is similar to but somewhat larger than the L6-S-A1 and L6-S-B1, this calculation was deemed satisfactory as a basis for comparison and no calculations were therefore prepared on the L6 vessels. In the calculations which were made on the Great Lakes bulk carrier "Enders M. Voorhees," the most favorable conditions of loading were assumed. The cargo was distributed in accordance with the standard loading practice which is designed to produce a minimum bending in the ship's hull girder as a result of the cargo distribution. The tankage conditions which were assumed in connection with the calculations are given in an addendum.

A comparison has been made between the bending strength of the Maritime Commission designs and the legal minimum requirements. There are tabulated below comparative figures for several designs showing the required and available section moduli each calculated in accordance with Section 43.37 of the Load-Line Regulations.

Type of Vessel	Required Section Modulus	Available Section Modulus
C1B	18,100 in² ft.	18,835 in² ft.
C2	20,900 in² ft.	23,460 in² ft.
C3	28,630 in² ft.	29,250 in² ft.
EC2-S-C1	18,900 in² ft.	21,400 in² ft.
T2-SE-A1	33,600 in² ft.	36,840 in² ft.

Part B. Data on Over-all Hull Girder Strength Obtained by Tests in Still Water

Full-scale hogging and sagging tests, coupled with strain measurements, have been made on five ships, one T2 tanker and four L6 ore carriers. The conclusions made from these tests, as related to the over-all hull girder strength, are summarized below and are shown graphically* in the following illustrations:

1. The hull structure of the vessels tested behaves essentially as a simple beam in bending. Longitudinal stresses and hull girder deflections are in reasonable agreement with the calculated theoretical values. Variations between computed and measured values, in most cases, are of the order of the accuracy involved in such field measurements.

2. The longitudinal material appears to be adequately and efficiently disposed. Deck stresses are of uniform intensity across the strength portion of the deck in both types of vessels. The deck plating between hatches on ore carriers carries negligible longitudinal stress. The combination riveted and welded structure in the latter design works integrally and in a homogeneous manner.

3. No abnormally high stresses or unusual behavior have become apparent from testing these structures under static conditions.

4. The gages used for making test were 10 in. and greater. No stress concentration of a magnitude sufficient to explain rupture of plating were found within the gage length used.

Part C. Data on Stress Concentrations Obtained During Full-Scale Tests in Still Water

"Shiloh"

1. The over-all stresses in the fashion plate at the aft end of the midship deckhouse were comparable in magnitude to the main deck stresses amidships. Stresses at the abrupt end of the fashion plate where it joins the sheer strake were probably higher but no measurements were made because the gaging technique did not permit measuring stresses in such localized areas.

2. The detail of joining the longitudinal and transverse bulkheads causes abrupt discontinuities and definite stress concentrations were measured. It was not possible to evaluate the stress concentrations quantitatively because of gaging difficulties.

Great Lakes Ore Carriers

1. Discontinuities such as cargo hatches, access doors and ports were found to cause stress concentrations. Measurements near such discontinuities gave stress concentrations of 1.5 but the long base length of the gages limited the measurements because it was not possible to make observations at the point of highest concentration.

General

An earnest attempt has been made to evaluate the stress concentrations. The three statements above are gleaned from a mass of experimental data and represent the best rational summation of the results obtained. It should be recognized, however, that the long base gages employed and the inherent difficulties of mechanical gaging technique made it impossible to measure strains at critical points which would be expected to show maximum concentrations of stress. Subsequent to the performance of the work on which the above conclusions are based, additional investigations have been made employing electrical resistance strain gages which have made it possible to measure strains closer to the critical points of concentration.

* Not reproduced.

Exhibit IV

SURVEY OF RESEARCH PROJECTS, APRIL 1, 1945

I. Introduction

As a result of structural failures of welded ships numerous research investigations were started at the instigation of the Board convened April 20, 1943, by the Secretary of the Navy to investigate the design and methods of construction of welded steel merchant vessels, and by other governmental and private agencies to determine the relative importance of the various factors which at that time were thought to contribute to those failures.

The research investigations which have been undertaken to determine the cause, or causes, of failure in welded steel ships may be classified as follows:

1. Design.
2. Materials.
3. Fabrication.

The Research Advisory Committee, appointed to take cognizance of, coordinate and evaluate all research work which is considered to have a bearing on the problem, hereby attempts for the first time to evaluate the results of these investigations.

In presenting this summary, the Committee desires to draw attention to the fact that the majority of the results obtained to date deal with the subject of fabrication and in particular with that of residual welding stresses. This emphasis on residual welding stresses reflects the importance which was attached to this subject by the majority of the technical personnel in the industry, when the research program was initiated, whereas the full significance of the type of fracture encountered in ship failures was not recognized until recently. The studies now under way on materials have not proceeded to the point where final conclusions based on complete test data may be presented, even though during the last six months greater emphasis has been placed on the investigations of materials.

II. Discussion of Results

1. Design

Full-scale tests on welded ships have corroborated earlier experiments in riveted ships and confirmed the validity of the basic analytical methods in calculating the stresses in the main hull girder. Application of this method to present welded ships indicates a general level of stresses comparable to those of riveted ships. There are several research projects which have contributed significantly to design details. These projects have investigated stress distributions on board ship during loading and at sea, around such structural discontinuities as hatch corners, and much experimental data are at present being analyzed. In one investigation a strain concentration of 7 was measured at sea. This unexpectedly high value is of great significance and warrants considerable additional research.

2. Materials

A substantial random selection consisting of 257 samples of steel was collected from the stock and scrap piles of shipyards constructing merchant vessels; 1028 tensile tests from these samples indicated that practically all of this steel complied with existing specifications for physical properties.

Notched-bar impact tests on rimmed, semikilled and fully killed grades of ship steel have shown that the transition from ductile to brittle behavior occurs at a relatively low temperature for fully killed steel, at a temperature as high as 90° F. for some heats of rimmed steel, and at intermediate temperatures for semikilled grades. Some semikilled grades had transition temperatures as high as some of the rimmed steel heats.

Charpy impact tests have shown that the notch toughness of weld metal, including the heat-affected zone, is equal to or better than that of the base metal.

Tests of large tubular specimens $^3/_4$ in. thick under conditions of biaxial stress and −40° F. temperature have produced brittle failures on semikilled ship plate exhibiting as little plastic flow as has been observed on ship failures. The magnitude of stress at which such failures were produced was considerably below that of the uniaxial coupon stress.

Tests of large notched plates $^3/_4$ in. thick of ship steel under uniaxial tension load have produced brittle failures with low plastic flow at temperatures as high as 90° F. At temperatures of 32° F. brittle failure was produced in the case of one plate 72 in. wide at 29,000 psi. average stress in the net cross section.

It is believed that the lack of notch toughness at low temperatures, and the loss of strength and ductility under multiaxial stresses of shipbuilding steels is a prime factor in the failure of welded ships. It should be noted that these properties are not recognized in the existing specifications.

Investigations are now in progress to secure additional data on the strengths of different types of ship plate when subjected to multiaxial stresses at various temperatures. These studies include the testing of large tubular specimens under biaxial tension, of notched plate specimens and of full-scale portions of ship's structure.

3. Fabrication

As mentioned in the introduction, the large part of the investigation covering this subject has thus far dealt with the matter of residual and locked-in stresses where the former are envisaged as being the by-product of welding unrestrained members, whereas the latter include also stresses resulting from other fabrication and assembly processes.

(*a*) *Residual Welding Stresses.*—It has been established that a reproducible pattern of high longitudinal tension stress and low transverse stress exists in all butt-welded joints in free ship subassemblies. The magnitude of these stresses in such subassemblies is not appreciably modified by welding sequence. Residual stresses are not affected by the type of electrode commonly used for ship fabrication nor by the use of austenitic 18–8 electrode.

The above must not be construed to mean that proper welding of erection sequences are not important in preventing cracking and distortion during construction.

It has been determined that with a particular method of block-welding procedure in which block welds of not more than 5 in. in length are used, a reduction in the resulting residual welding stress of approximately 50% is possible. It should be noted, however, that this method requires that the temperature of the welded block be 125° F. or less before the next succeeding block is deposited. The method appears to have merit for special application, but because of the obvious loss of welding time does not appear suitable for general use in ship welding.

The residual welding stresses may be reduced 50% or more in case of simple butt-welded joints in free subassemblies, by the application of a controlled low-temperature stress-relieving treatment, producing a tempera-

SURVEY OF RESEARCH

PERTAINING TO

INVESTIGATION OF WELDED SHIPS

LINE	PROJECT	LOCATION	DESCRIPTION	PERCENT COMPLETE	RESULTS
1	NRC-53	M.I.T.	RESIDUAL STRESS VS. BALLISTIC PERFORMANCE ARMOR	100%	ON 1" ARMOR PLATE, RESIDUAL STRESSES (1) ARE BI-AXIAL, STRESS THROUGH THICKNESS APPROXIMATELY 0, (2) ARE NOT INFLUENCED BY DIFFERENT ELECTRODES, (3) DO NOT AFFECT PERFORMANCE IN EXPLOSION OR BALLISTIC SHOCK TEST.
2	NRC-64	U.C.	RESIDUAL STRESSES - SHIP WELDING	100%	1" PLATE TESTED - RESIDUAL WELD STRESSES ARE (1) HIGH LONGITUDINALLY (47,000 P.S.I TENSION), (2) LOW TRANSVERSELY (15,000 P.S.I. TENSION OR COMPRESSION), (3) UNAFFECTED BY SEQUENCE IN FREE ASSEMBLIES, (4) REDUCED BY (A) BLOCK WELDING, (B) CONTROLLED LOW TEMPERATURE STRESS RELIEF, (C) MECHANICAL LOADING, (D) SPECIAL PEENING.
3	NRC-65	R.P.I.	CRACK SENSITIVITY - WELDS	100%	STRESS PATTERNS IN ¾" AND ½" BUTT WELDS IN SHIP PLATE USING SEVERAL TYPES OF ELECTRODES AND WITH VARIOUS DEGREES OF RESTRAINT HAVE BEEN DETERMINED, AND INDICATIONS OF STRESSES NECESSARY TO PRODUCE CRACKING OBTAINED.
4	NRC-72	M.I.T.	DUCTILITY - WELDED MEMBERS	100%	TEMPERATURE AT WHICH BRITTLE FRACTURE OCCURS IN NOTCHED BEND SPECIMENS VARIES WITH (1) THE STEEL USED, (2) WHETHER WELDED OR UNWELDED, (3) IN WELDED SPECIMENS, WHETHER "AS-WELDED" OR POLISHED.
5	NRC-74	U.C.	HISTORY - RESIDUAL STRESSES WELDED SHIPS	80%	(1) AVERAGE FORE AND AFT STRESSES IN DECK PLATES (AWAY FROM WELDS) ARE COMPRESSIVE AND INCREASE FROM 2000 TO 6,000 P.S.I. FROM SUB-ASSEMBLIES TO COMPLETED LIBERTY SHIPS. (2) RESIDUAL STRESSES IN DECK WELDS IN OLD AND NEW LIBERTY SHIPS AND SUB-ASSEMBLIES SHOW NO SIGNIFICANT DIFFERENCES. THE MAGNITUDE OF THE LONGITUDINAL STRESSES ARE IN THE REGION OF 35,000 TO 40,000 P.S.I. IN TENSION. (SEE ALSO NO 18) (14 SHIPS TESTED)
6	NRC-75	U.C.	MULTI-AXIAL STRESS - SHIP STEEL - LARGE TUBES - WELDED	90%	A- ON LARGE WELDED TUBES (20" DIA, 10' LG) UNDER BI-AXIAL LOADING, (1) APPRECIABLE DUCTILITY IS EXHIBITED AT ROOM TEMPERATURE IRRESPECTIVE OF STRESS RATIO AND/OR RESIDUAL STRESS PRESENT. (2) AT -40°F. BRITTLE FAILURES OF THE TYPE ENCOUNTERED IN SHIPS OCCURRED IN AS-WELDED TUBES. B- ON FLAT NOTCHED SPECIMENS UNDER UNI-AXIAL LOADING, (1) CLEAVAGE FRACTURES WITH LOW DUCTILITY OCCUR ON SAME SHIP PLATE AT ROOM TEMPERATURE, (2) BRITTLE FRACTURES WITH ULTIMATE AVERAGE STRESS OF 39,000 P.S.I OCCUR AT +32°F ON SAME SHIP PLATE WITH CERTAIN NOTCHES.
7	NRC-77	I.I.T.	MULTI-AXIAL STRESS - SHIP STEEL - SMALL TUBES	75%	WELDED AND UNWELDED TUBES UNDER BI-AXIAL LOADING AT ROOM TEMPERATURE EXHIBIT GOOD DUCTILITY. THE TRUE STRESS AT FRACTURE IS SOMEWHAT LOWER THAN UNI-AXIAL TEST SPECIMENS.
8	NRC-82	CAL. TECH.	STELL DYNAMIC LOADING (SPECIMENS 0.306" DIA)	100%	SAE 1015 HOT ROLLED STEEL UNDER DYNAMIC LOADING (25' TO 200') PER SECOND AT ROOM TEMPERATURE SHOWS 50% HIGHER ULTIMATE STRESS AND ENERGY ABSORPTION, NO SIGNIFICANT CHANGE IN DUCTILITY.
9	NRC-86	LEHIGH	WELDABILITY - CRACK SENSITIVITY - STEEL	25%	(SEE NO. 10)"
10	NRC-87	BATTELLE	METALLURGY - STEEL	25%	TO DATE ALL WORK HAS BEEN PERFORMED ON H.T.S., BUT MEDIUM STEEL WILL ALSO BE INVESTIGATED.
11	NRC-89	CORNELL	FATIGUE - SHIP WELDS	10%	NO RESULTS AS YET - SEE NO. 22
12	NRC-92-A	U.C.	CLEAVAGE FRACTURE FLAT PLATES - SEMI-KILLED SHIP STEEL	10%	PRELIMINARY TESTS AT LOW TEMP AND HIGH STRESS GRADIENTS SHOW LOW DUCTILITY OF THE ORDER OF 2% OR IN SHIPS.
13	NRC-92-B	U.C.	CLEAVAGE FRACTURE - SHIP STEEL - STRUCTURAL SPECIMENS	15%	A CARGO HATCH CORNER DETAIL HAS BEEN SELECTED AS THE STRUCTURAL SPECIMEN TO BE USED. STRESS DISTRIBUTIONS AROUND LIBERTY SHIP HATCH CORNER OBTAINED DURING LOADING AND AT SEA. STRAIN CONCENTRATION OF SEVEN OBTAINED AT HATCH CORNER IN MODERATE SEA.
14	NRC-93	U. ILL.	CLEAVAGE FRACTURE FLAT PLATES - RIMMED AND KILLED SHIP STEEL	10%	INTERNAL NOTCHES TERMINATING IN JEWELER'S SAW CUT, AND FATIGUE CRACK ALL PRODUCE CLEAVAGE FRACTURE AT SAME TEMPERATURE, SAME ENERGY ABSORPTION. ENERGY ABSORPTION AND AVERAGE ULTIMATE STRESS DROP RAPIDLY AS NOTCH WIDTH TO SPECIMEN WIDTH RATIO INCREASES.
15	NRC-94	CARNEGIE	DEV. NEW NOTCH SENSITIVITY TEST - SHIP STEELS	10%	NO RESULTS AS YET
16	USMC-SCHUYLER		HATCH CORNER STUDY: FULL SCALE	80%	EXTENSIVE DATA BEING ANALYZED. REPORT IN PREPARATION
17	TMB		HATCH CORNER STUDY (PHOTO-ELASTIC-MODELS)	50%	NO RESULTS AVAILABLE - DIFFICULTIES HAVE BEEN EXPERIENCED IN BUILDING MODELS.
18	TODD-HOUSTON		STRESSES - WELDED SHIPS	75%	(1) FORE AND AFT STRESSES IN DECK PLATES (AWAY FROM WELDS) IN COMPLETED LIBERTY SHIPS AVERAGE 6300 P.S.I IN COMPRESSION. (2) THE LONGITUDINAL RESIDUAL WELD STRESSES IN THE DECKS OF COMPLETED LIBERTY SHIPS ARE IN THE REGION OF 35,000 TO 40,000 P.S.I. IN TENSION (SEE ALSO NO 5) (FIVE VESSELS INVESTIGATED)
19	BETH.-QUINCY		STRESSES - WELDED SHIPS AND MODELS	UNKNOWN	RELAXATION MEASUREMENTS ON DECKS OF COMPLETED LIBERTY SHIPS CONFIRM FINDINGS OF PROJECTS (5) AND (18).
20	SUN-LINDE		CONTROLLED LOW TEMPERATURE STRESS RELIEF	UNKNOWN	RESIDUAL STRESSES IN DECK AND SHELL PLATING WELDS CAN BE REDUCED 50% OR BETTER BY THIS METHOD ON BUTT WELDS.
21	CARNEGIE-ILL.		STRENGTH - WELDED SHIP JOINTS	100%	WELDS PARALLEL TO LOAD DECREASE DUCTILITY BUT DO NOT AFFECT STRENGTH RELATIVE TO COUPON, CLEAVAGE FRACTURE DOES NOT NECESSARILY INDICATE LACK OF DUCTILITY, STRUCTURAL DISCONTINUITIES ARE POINTS OF WEARNESS EVEN UNDER STATIC LOAD, AT CORRESPONDING TEMPERATURES NOTCH-BAR TOUGHNESS OF BASE METAL, FUSION ZONE AND WELD METAL COMPARE FAVORABLY AT ROOM TEMPERATURE AND +20°F, BOTH AS-WELDED AND STRESS-RELIEVED SPECIMENS EXHIBIT GOOD DUCTILITY, ALTHOUGH DUCTILITY OF THE LATTER IS SOMEWHAT BETTER.
22	U.S.C.G.	U. ILL.	FATIGUE - SHIP PLATE (NOTCHED)	10%	NO RESULTS AS YET
23	W.R.C.	I.I.T.	FATIGUE - BI-AXIAL - STEEL - SPECIMENS	15%	NO RESULTS PERTINENT TO INVESTIGATION TO DATE
24	T.M.B.	WEMCO	MULTI AXIAL STRESS - THIN STEEL & COPPER TUBES	100%	RESULTS NOT PERTINENT TO INVESTIGATION

SURVEY OF RESEARCH
PERTAINING TO
INVESTIGATION OF WELDED SHIPS

LINE	PROJECT	LOCATION	DESCRIPTION	PERCENT COMPLETE	RESULTS
25	N.Y.N.Y.		STEEL SPECIFICATION IMPROVEMENT	50%	NO RESULTS AVAILABLE AS YET
26	U.S.C.G.	BU.STDS.	ANALYSIS - STEEL - FRACTURED VESSELS	CURRENT	NO RESULTS AVAILABLE AS YET
27	U.S.N.E.E.S.		CRACK PROPAGATION - STRESSES FOR	100%	REPORT REQUESTED
28	U.S.N.	BU.STDS.	PROPERTIES OF SHIP STEEL	100%	(1) 18 SHEARED AND STRIP MILL STEELS FROM SIX SOURCES TESTED. ALL MET SPEC. 48-S-S. (2) CHARPY V-NOTCH TESTS SHOW (A) RIMMED STEELS IN GENERAL SHOW LOWER NOTCH-TOUGHNESS VALUES THAN SEMI-KILLED STEELS (B) TRANSITION TEMPERATURE TO BRITTLE FRACTURE IN LINE 21 OCCURS AT HIGHER TEMPERATURE FOR RIMMED STEELS (C) SOME HEATS OF SEMI-KILLED STEELS NO BETTER THAN RIMMED STEELS (D) NORMALIZING TENDS TO IMPROVE ALL VALUES.
29	W.R.C.	CASE	MULTI-AXIAL TENSION - WELDED STEEL STRUCTURES	0	NO RESULTS AS YET
30	W.R.C.	BU.STDS.	RESIDUAL STRESS & CONSTRAINT WELDED STRUCTURES	0	NO RESULTS AS YET
31	W.R.C.	M.I.T.	RESIDUAL STRESSES - WELDING	UNKNOWN	NO RESULTS AS YET
32	W.R.C.	BRLYN. POLY.	PEENING	UNKNOWN	INSUFFICIENT DATA PRESENTED TO PROPERLY JUSTIFY CONCLUSIONS
33	U.S.C.G.	U.ILL.	BRITTLE FRACTURE STUDIES - NOTCHED SHIP PLATE	100%	BRITTLE CLEAVAGE FRACTURE PRODUCED IN SHIP PLATE AT +32°F. WITH INTERNAL NOTCH, AFTER STRAINING AND AGING. AVERAGE ULTIMATE STRESS AT FRACTURE 35,000 P.S.I.
34	U.S.C.G.	MODEL BASIN	TENSION TESTS NOTCHED PLATES - NARROW BARS	20%	ON RIMMED STEEL TESTED, (1) CLEAVAGE FRACTURE OCCURS UP TO 90°F. (2) ENERGY ABSORPTION DECREASES AS TEMPERATURE DECREASES (3) ENERGY ABSORPTION IS MUCH GREATER WITH NARROW NOTCHES

ture differential between the weld and base metal. Its effectiveness in geometrically more complex joints or structures has not been so far demonstrated.

Peening the last pass of the welds will also materially reduce the magnitude of residual welding stresses. On the basis of investigations performed, it does not appear that peening other passes than the last will affect reductions of final residual stresses. This statement, however, must not be construed to mean that peening intermediate and root passes is not helpful in preventing weld cracking and in controlling distortion.

It has been found that residual welding stresses can be relieved by the application of external load causing plastic flow of the weld metal and adjacent area. Conditions of external restraint tending to inhibit plastic flow in the weld area will reduce the amount of stress relief taking place. Such conditions apparently exist in varying degrees on board ship because on eight Liberty ships investigated to date the residual stresses in the deck joints abreast of No. 3 hatch were not "worked out" or even reduced significantly after considerable service. A small reduction of residual stress was observed on two tankers subjected to severe hogging and sagging tests, but the magnitude of reduction was very much less than what could be expected in unrestrained welds subjected to the same unit loadings. Preheating ship steel up to 375° F. does not achieve significant reductions in residual welding stresses.

Tests of large tensile specimens of ship steel up to 30 sq. in. in cross-sectional area were made in order to compare "as-rolled" plate with longitudinally welded plates both in the "as-welded" and stress-relieved conditions. Those tests showed that the elongations of "as-welded" plates were somewhat less than those obtained in either "as-rolled" plate or welded plate which had been stress relieved. However, the large amount of plastic flow which preceded failure in the "as-welded" plates does not in any way duplicate the brittle fractures with barely measurable plastic flow which have been characteristic of the ship failures.

Tests of large tubes of both 1/4- and 3/4-in. thick ship plate, in both stress-relieved and "as-welded" conditions, subjected to biaxial tension stresses again indicated ability of plate and welds to undergo large plastic flows irrespective of the presence of residual welding stresses.

In general, it may be concluded that the contribution of the residual welding stresses to the failure of welded steel ships has not yet been fully determined. Preliminary results of all investigations of this subject indicate to date that residual stresses do not contribute to the failure of welded structures except possibly under some special conditions of stress, inhibiting shear flow.

Some indications exist that the effect of metallurgical changes caused by welding process is more important in the properties of welded structures than that of residual welding stresses.

(*b*) *Locked-In Stresses.*—Considerable research is now in progress investigating the magnitude of the locked-in stresses which are defined as all stresses resulting from fabrication and assembly processes.

Up to the present time no tensile locked-in stresses have been observed in deck plate of approximately 30 ships investigated by three independent agencies and representing ships built in a variety of shipyards and with a number of erection sequences. The locked-in deck plate stresses are of the order of 4000–8000 psi. in compression in the fore and aft direction.

Investigation of locked-in stresses is being continued to include effect of unusual climatic conditions.

III. Conclusions

On the basis of the data available to date, the following conclusions are drawn:

1. Residual welding stresses do not contribute materially to the failure of welded structures.
2. Locked-in stresses in the deck plating (away from welds) of completed ships are generally compressive and of low magnitude (4000–8000 psi.).
3. Residual welding stresses in completed vessels are not appreciably reduced by normal service.
4. Lack of notch toughness at low temperature and loss of strength and ductility under multiaxial stresses, of steels used in ship building is a prime factor in the failure of welded ships.

5. Large tubular specimens of ship steel, with and without welds, tested under biaxial tension and especially at low temperature, show great reduction in strength and ductility as compared with results from usual tensile tests at corresponding temperatures. At −40° F. lack of plastic flow was comparable to that found on ship fracture.

6. Large notched specimens of ship plate tested at 32° F. produced brittle failures at half the nominal strength with lack of plastic flow comparable to ship fractures.

7. Very high stress concentrations exist in the hull structure of ships. A strain concentration of 7 has actually been measured on a cargo hatch corner, the vessel being at sea.

8. Welding sequence in general has no effect upon the magnitude of residual welding stresses in free subassemblies.

9. Residual welding stresses may be reduced by peening the last pass of manual welds.

10. Residual stresses are not reduced by preheating up to 375° F.

It must be reiterated that the above conclusions are based on data produced to date. Additional data which are expected shortly from the research now under way may necessitate revisions or modifications of some of these conclusions.

G. S. MIKHALAPOV

Exhibit V

SURVEY OF SHIPYARD WELDING PRACTICES, MAY 1, 1945

Sub-Board Report on Shipyard Conditions Surrounding the Construction of Welded Steel Vessels as Witnessed by the Welding Advisory Committee in 33 Shipyards

The following report is based upon the data collected by the Welding Advisory Committee in touring 33 shipyards on the East, Gulf and West Coasts. It comprises a review of the most pertinent facts, with a statement of additional studies which are suggested by the data.

I. Welder Training and Advancement

Qualification tests for the welding operators are done on the same equipment, with the same instructor and under the same circumstances used for the schooling but the qualification card is unrestricted and permits the welding operator to move from place to place and perform work with different brands of equipment. The qualification tests are performed at the welding school under circumstances which do not encourage the trainee to rely on his own ability. The qualification tests are done under conditions which are extremely favorable to the preparation of satisfactory specimens and do not simulate shipboard conditions. Only one yard attempted to simulate shipboard conditions in testing the welding operator, requiring him to prepare his test specimens in cramped positions. Qualification tests do not include the use of different grades and types of electrodes. Instead, they are generally performed with that electrode which prepares a satisfactory test specimen with a minimum of manipulation ability on the part of the operator. The reports indicate quite definitely that there is a wide variation in training between the various yards and that there is a wide discrepancy between the capabilities of welders of the same grade in different yards. Few yards require practical experience between the up-grading in rating. The reports on the welding schools indicate that there is a definite need for a well-defined and uniform system for training both tack and production welders.

Except in isolated cases, there is no means by which an inspector can readily identify the qualification of a man on the job. He must ascertain the man's badge number and consult the company files for further information. A few yards have found it possible to overcome this difficulty by the use of colored badges for the welders or special marks on the helmets and wire buckets. The question of welding operator identification needs further study.

One yard has a welding operator turnover of 12% a year while nine other yards have turnovers greater than 100% a year. Such a circulation of welding operators is not conducive to maintaining high quality of welding. The tremendous range in turnover of welding operators between the various yards indicates the necessity of a further study to determine the reasons for this turnover.

II. Incentive for Good Workmanship After Graduation

In most yards which have a piecework system the piecework system entirely nullifies other monetary incentive for good workmanship. One yard developed a piecework system which includes a partially satisfactory arrangement for additional compensation for good workmanship. In the non-piecework yards there is no incentive to do poor work; on the other hand, there is likewise no incentive to do good work except in the case of one yard, which keeps a record of the quality of work performed by the welder.

III. Supervision

The reports indicate that there is a wide variation in the number of welding operators under each supervisor. The data on the supervision of welding indicate that the line of authority in nearly every yard is different. In many shipyards, the shipfitting department is able to force acceptance of poor fitting and the administrative setup places the responsibility for maintenance of welding sequence in the hands of production men. The welding engineer usually serves in an advisory capacity and generally lacks authority to enforce good welding practices. A study of the administration of shipyard welding departments is needed.

IV. Inspection

The reports indicate that about one-third of the yards trepan certain welds to check penetration, porosity, etc. Some of the yards which trepan welds indicate that this inspection has proved very satisfactory because the welding operators all take greater care in making the welds when they know that there is a possibility that the welds may be trepanned. The successful operation of this method in several shipyards suggests the possibility of extending the internal examination of welds to other yards, but the reports indicate that if trepanning is used, the plugs should be etched to permit thorough examination.

It is noted that some of the yards can trace work to the individual welder. When such yards make subsurface inspection of welds, the psychological effect on the welding operators resulted in an improvement in the quality of welding. Some of the yards have an inspection

department but it is responsible to the production department and therefore somewhat ineffectual. A study of this organizational setup appears to be needed.

One of the most important findings of the committee is that many of the yards caulked leaky welds in both watertight and non-watertight structure. This is a particularly serious matter in the strength members of the main hull structure because it means that internal cracks are being covered up by bobbing the material over them and these cracks are being left in the structure as potential triggers for a subsequent structural failure.

V. Production

The reports on production are encouraging in that they show care in the preparation of welding and erection sequences but they also show that the sequences are not being rigorously followed. There appears to be a need for improved administrative action in giving effect to the welding sequence.

Many approved joint preparations now in use are not making good welds in production because the joint details selected are often not suitable for the particular location.

The reports point to the need for a study of the type of plate edge preparation for production of the most satisfactory welds for various types of machine and manual welding. Many data of this nature are already available but it is evidenced from the variety of details now in use that full advantage is not being taken of available data.

The reports point to the need for a continuance of the efforts to reclassify and limit the use of various types of electrodes.

In many cases, weld passes were not cleaned. Failure to back-chip is prevalent and the reports indicate that many of the yards are failing to chip to sound metal or a sharp V is left in the root and the weld does not fully penetrate. Such a practice is just as serious as bobbing over a crack because it leaves a small sharp cavity in the interior of the weld which may later lead to a structural failure.

Machine welding needs further consideration from a technical standpoint with a view to furnishing additional data and instructions to the shipyard.

VI. Workmanship

The report of workmanship indicates that there is still considerable room for improvement.

In light of these data and in view of the difficulty of increasing inspection forces or altering yard administration, there is a need for a study of the possibility of providing an integrated program of subsurface inspection coupled with welding operator identification to alleviate the conditions set forth in Parts II to VI, inclusive.

VII. Structural Details

It was noted that eight yards are still building vessels with square hatch corners. Sheer strakes in all but two yards still support an accumulation of accessories and bilge keels are not properly treated in several yards. Corrective measures by the four parent agencies of the Board are needed.

VIII. Erection Methods

The report on erection methods indicates that the situation is generally good. The majority of the yards use rigid strongbacks. The use of numerous rigid strongbacks appears to produce no deleterious effects.

IX. Reception of Advisory Committee

In general, the Committee was well received.

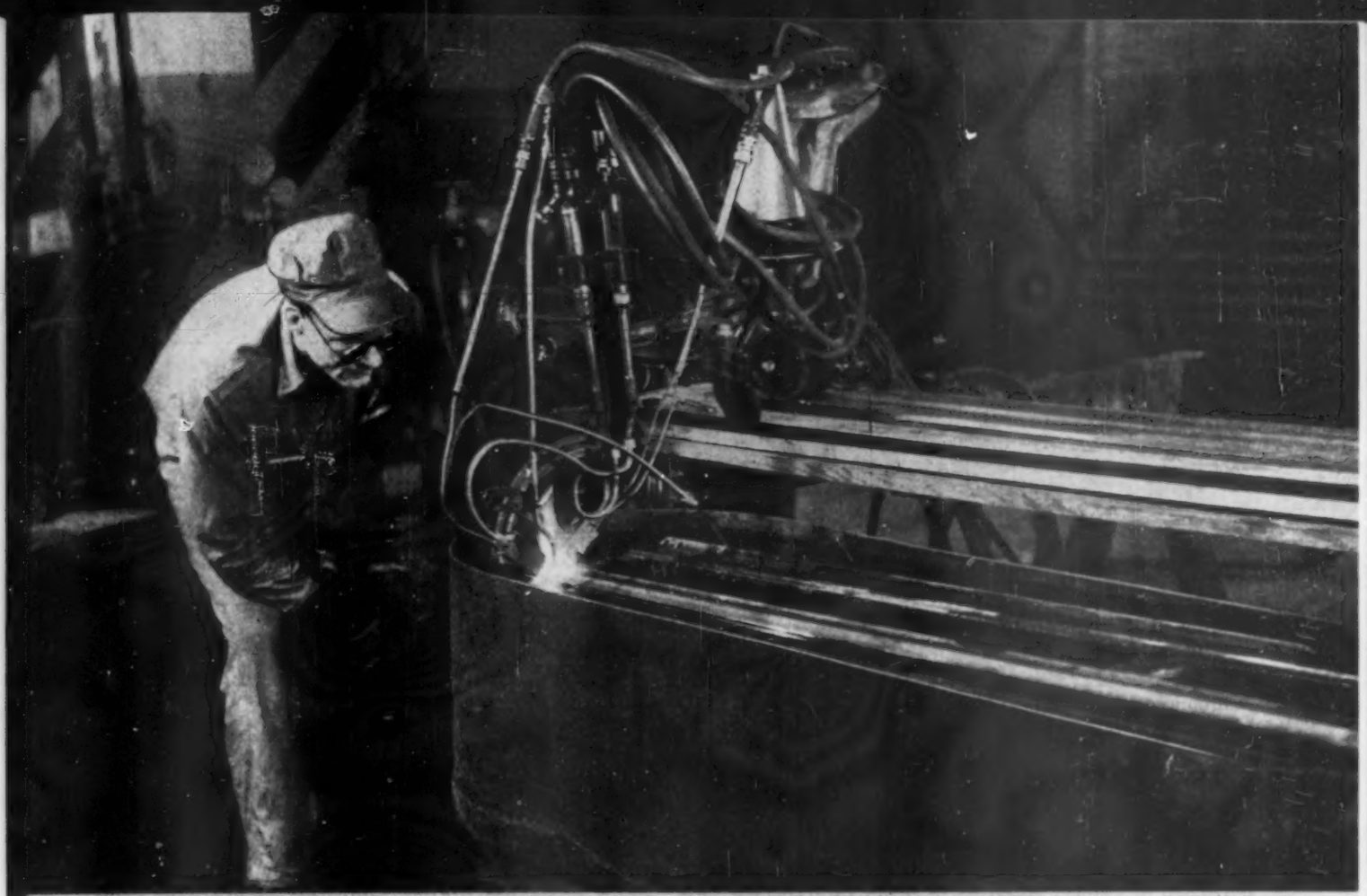
X. Attitude Toward U. S. Maritime Commission Instruction Booklet

The results of the survey regarding the instruction booklet prepared by the Maritime Commission indicate that this pamphlet has not reached many of the people for whom it was intended and, furthermore, it points to the need for continued activity along identical lines.

It is the opinion of the Sub-Board that the Welding Advisory Committee has performed a very valuable service and has uncovered a great deal of information pointing to the need for further study and administrative action along the lines indicated in the preceding summary of their findings. The principal points have been so well brought out by the investigation of the 33 shipyards studied.

The Sub-Board finds that the four parent agencies, namely, Navy Department, Maritime Commission, American Bureau of Shipping and Coast Guard are collaborating through existing channels in making studies and investigations along the lines indicated in this report and that appropriate steps are being taken to give effect in so far as practicable to the findings of this and subsequent investigations.

L. A. KNISKERN, Captain, USN



Flame-Hardening in the Small Shop

By William B. Sharav*

FLAME HARDENING is a method of creating a hard wear-resisting surface on a suitable ferrous material by quenching after rapidly heating the surface with an oxyacetylene flame. Inasmuch as the chemical composition of the material is not altered, this process is only applied to such ferrous materials as cast iron and steel which will respond to quench hardening. Flame-hardened parts have the desirable properties of a hard, wear-resisting surface on a tough, shock-resisting core.

As the definition implies, the essential elements of a flame-hardening setup are a blowpipe for controlling the oxyacetylene flame and a means of quenching the heated part. This article illustrates and describes a number of simple setups that small shops have found useful for small-lot production flame hardening.

Flame-Hardening Methods

There are four general methods of flame hardening in common practice. The first and most simple procedure is that which is commonly called "spot hardening." This involves the heating of only a small localized area, such as the tip of a valve stem, to a red heat and then rapidly cooling that area.

A second method of treatment, most suitable for flame-hardening flat surfaces, such as large gear teeth or machine-tool ways, is known as the progressive method. By this method, an oxyacetylene flame or group of flames

Method	Blowpipe Action*	Action of Part	Example
Spot	Stationary	Stationary	Valve Push Rod
Progressive	Moves Along Part	Stationary	Blade
Spin	Stationary	Rotates	Gear
Combination	Moves Along Part	Rotates	Shaft

* Quench action same as blowpipe action.

Fig. 1—The Principal Flame-Hardening Methods with the Relative Actions of the Blowpipe and the Part Being Hardened for Each Method Are Compared Above

* Development Engineer, The Linde Air Products Co.

Table 1—Steels Suitable for Flame Hardening

Type of Steel	S.A.E. Number	Composition Range, per cent						Expected Brinell Hardness, as quenched in—		
		Carbon	Manganese	Nickel	Chromium	Molybdenum	Vanadium	Water	Oil	Air
Plain Carbon Steels	1035	0.30-0.40	0.60-0.90					350-500		
	1040	0.35-0.45	0.60-0.90					450-550		
	1045	0.40-0.50	0.60-0.90					500-600		
	1050	0.45-0.55	0.60-0.90					550-650		
Medium-Manganese Steels	T-1330	0.25-0.35	1.60-1.90					450-500		
	T-1335	0.30-0.40	1.60-1.90					500-550	450-550	350-400
	T-1340	0.35-0.45	1.60-1.90					550-650	450-550	350-450
Nickel Steels	2335	0.30-0.40	0.50-0.80	2.25-2.75				450-500		
	2340	0.35-0.45	0.60-0.90	2.25-2.75				500-550		
	2345	0.40-0.50	0.60-0.90	2.25-2.75				550-600	400-500	
	2350	0.45-0.55	0.60-0.90	2.25-2.75				600-650	400-500	
Nickel-Chromium Steels	3130	0.25-0.35	0.50-0.80	1.00-1.50	0.45-0.75			400-500		
	3135	0.30-0.40	0.50-0.80	1.00-1.50	0.45-0.75			450-550	400-550	350-500
	3140	0.35-0.45	0.60-0.80	1.00-1.50	0.45-0.75			550-650	400-550	350-500
Chromium-Molybdenum Steels	4135	0.30-0.40	0.60-0.90		0.80-1.10	0.15-0.25		400-500		
	4140	0.35-0.45	0.60-0.90		0.80-1.10	0.15-0.25		450-550	400-550	350-500
	4150	0.45-0.55	0.60-0.90		0.80-1.10	0.15-0.25		550-650	400-550	350-500
Chromium Steels	5140	0.35-0.45	0.60-0.90		0.80-1.10			450-550		
	5150	0.45-0.50	0.60-0.90		0.80-1.10			550-650		
Chromium-Vanadium Steels	6135	0.30-0.40	0.60-0.90		0.80-1.10		0.15-0.20	450-550		
	6140	0.35-0.45	0.60-0.90		0.80-1.10		0.15-0.20	550-600	400-550	350-500
	6150	0.45-0.55	0.60-0.90		0.80-1.10		0.15-0.20	550-650	400-550	350-500

of the required width is passed over the surface to be hardened at such a speed as to bring that surface to a bright-red heat under the flame. The heated area is quenched by a stream or spray of water which moves with and immediately behind the flame at a point where it will provide the proper quenching effect and yet not interfere with the flame.

A third method of applying the flame-hardening process is known as the spinning method. In this type of treatment, a round or cylindrical piece to be treated, such as a small gear or pulley, is revolved in front of an oxyacetylene flame until the path immediately under the flame is brought to the required red temperature. The heated area is then quenched by directing a stream of water on the spinning object after withdrawal of the flame, or by releasing the heated piece and allowing it to drop into a bath of water or oil.

The fourth method of applying the flame-hardening process is known as the progessive-spinning or combination method. As the name indicates, this method is actually a combination of the progressive and spinning methods. It is particularly satisfactory for treating long cylindrical objects, such as shafts and pump rods, when a hardened surface is desired over a considerable length. As the object is spun between centers past the oxyacetylene flame, the flame is also moved lengthwise along the rod or shaft, heating the surface to a bright red in passing. The quench follows the flame exactly as in the progressive method and is applied while the object is spinning.

For ready reference the various methods are compared in Fig. 1. The steels suitable for flame hardening are listed in Table 1.

Simple Flame-Hardening Setups

As pointed out, the elements of a flame-hardening set-up are a blowpipe and a quench. One of the simplest such setups is that for flame-hardening the ends of valve stems illustrated in Fig. 2. For this application a standard blowpipe equipped with a special multiflame head is used. The valves are placed head down in water and the operator heats one valve end at a time. When the flame is removed, the water closes around the tip providing an

Fig. 2—A Welding Blowpipe Equipped with a Multiflame Head Is Used for Flame Hardening These Valve Stem Ends at a Rate of 1000 per Hour

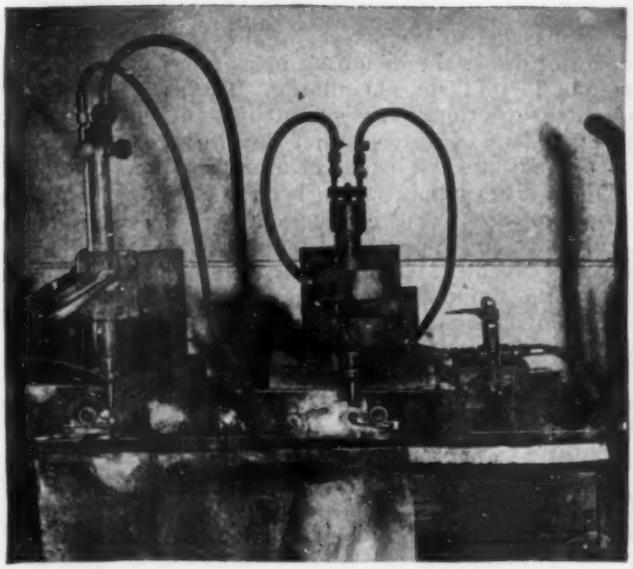


Fig. 3—This Setup for Flame Hardening the Lifter Pads on Valve Rocker Arms Was Assembled from Two Machine-Cutting Blowpipes—Equipped with No. 6 Nozzles and Supplied with Gases Through V-27 Valve

"automatic" quench. As many as 1000 valves are treated per hour with this spot-hardening setup.

Another example of spot hardening is the hardening of lifter pads on valve rocker arms. The setup is shown in Fig. 3 and it will be apparent from the two different blowpipes that any available apparatus was used to get into production as fast as possible. Although a more permanent setup could be built, the results would not be any better. The arms are mounted on pins protruding from the fixture and adjustable stops are provided to maintain the correct space between the pad and the tip. The cutting oxygen is not connected on the machine-cutting blowpipes. After the pads have been heated for the proper length of time, the rocker arms are slid off into a quench tank in front of the setup. As many as 350 arms per hour have been treated with this installation.

Fig. 5—In This Setup for Flame Hardening Valve Plugs the Purox 35 Welding Blowpipe Equipped with a No. 9 Head Is Mounted on a Grooved Block Which the Operator Slides Along a Square Bar Clamped at the Proper Angle

Another simple setup is shown in Fig. 4, for the flame hardening of plow shares. Here a welding blowpipe is fitted with a copper tube for the quenching water (attached with a C-clamp and a cable clamp) and the operator guides the combination slowly along the edge of the plow share. Notice that the plow share is tipped and that the flame-hardening operation starts at the nose and proceeds uphill, so that the quenching water will not run over the untreated surface.

Supporting Guides for the Blowpipe

A general rule in all flame-hardening operations is that the neutral oxyacetylene flame should be held as nearly

Fig. 4—In This Simple Setup for Flame Hardening Plow Shares a Welding Blowpipe with a No. 8 Head Is Used. The Tube Supplying Quenching Water Is Attached Directly to the Blowpipe

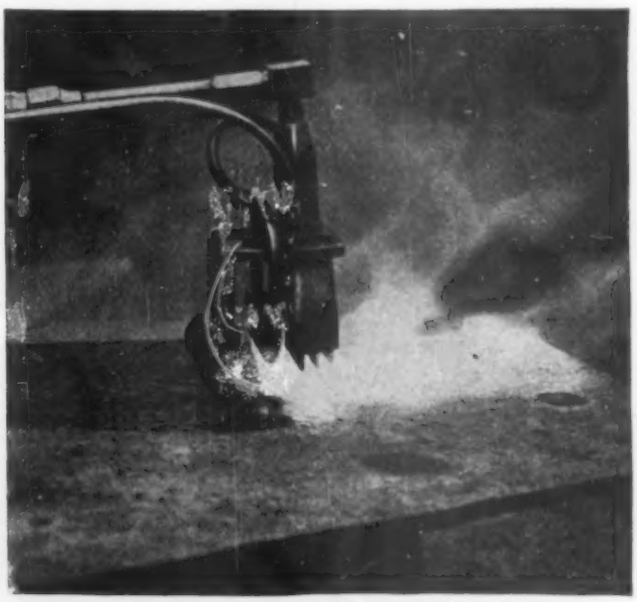


Fig. 6—This Rolling Rig for Flame Hardening Chute Liner Plates Consists of a Welding Blowpipe Equipped with a Right-Angle Adaptor and a 30-Flame Head. Quenching Water Cools the Heating Head Before Passing to the Quenching Spray

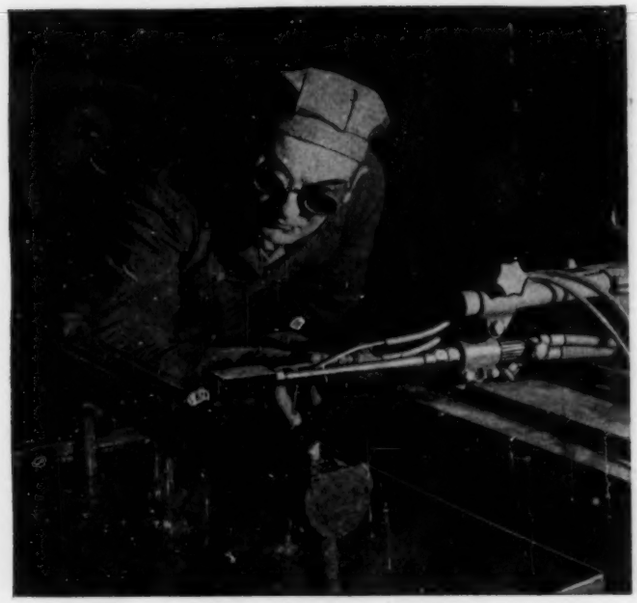


Fig. 7—A Cutting Machine and a Heavy Cutting Attachment Are Used to Support the Blowpipe Equipped with a Seven-Flame Head for Flame-Hardening Shredder Bars in This Setup

as possible at right angles to the surface being hardened, with the tip of the inner cone not closer than $^1/_{16}$ to $^1/_8$ in. from the metal. To help the operator maintain a constant distance between the inner cone and the surface of the metal it is usually desirable to provide some sort of a supporting guide for the blowpipe.

A simple guide of this sort is shown in Fig. 5. It consists of a mounting block for the blowpipe which moves along a 1-in. square bar clamped in the proper position. The part being hardened in this application is the plug for a plug valve used in the manufacture of high-octane gasoline. A welding blowpipe and a copper tube for the quenching water are mounted on the block. The track is set parallel to the surface of the valve plug and the operator draws the mounting block along it at a steady rate of 11 to 12 in. per minute. The plug is hardened one strip at a time. It is mounted on two pieces of scrap rail in a tank of water so that the area previously hardened is not affected by the heat of the flame. The tank is half a drum supported on sheet metal straps welded to scrap pipe legs.

Another simple device for maintaining a constant distance between the flame and the work is shown in Fig. 6, where the flame-hardening heads and the quench are mounted on small wheels. The operator watches the color of the metal and adjusts his speed accordingly. The part being hardened is a liner plate for a chute on a construction project. Since many of these liner plates must be hardened in place, it was necessary to have the apparatus completely portable.

The flame-hardening operations covered by Figs. 4 to 6 have been of the progressive method with a "hand-powered" blowpipe. Where a considerable number of parts are to be hard-faced, it is usually found to be more convenient to move the blowpipe by some motor-driven device.

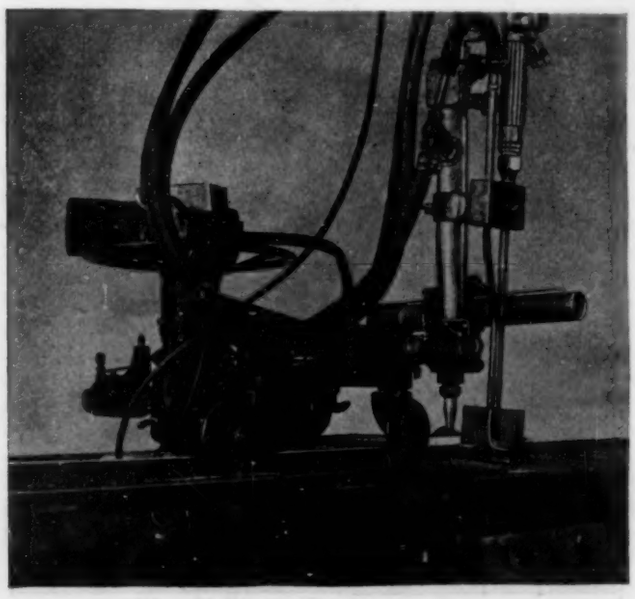


Fig. 8—In This Setup for Flame Hardening Long Knives the CM-16 Is Used for Cutting the Blades Out of Steel Plate as Well as for Carrying the Blowpipe and Specially Made Heating and Quenching Head

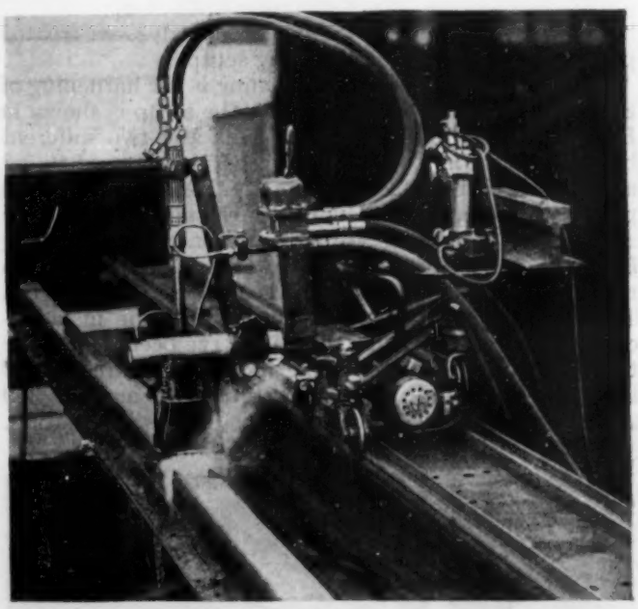


Fig. 9—A Blowpipe Equipped with a Standard Rhomboid Head Is Mounted on a CM-16 Cutting Machine in This Setup for Flame Hardening Sawmill Carriage Rails. Gases Are Fed to the Blowpipe Through a Quick-Acting Valve

Setups Moved by Cutting Machines

Figure 7 shows a simple setup for flame hardening shredder bars for pulp mill machinery. A standard portable cutting machine is used and a standard welding blowpipe is mounted on the heavy cutting attachment of the machine. In this case the blowpipe is fitted with a seven-flame head, but three tips are blanked off since they are unnecessary. The blade is immersed in water up to a short distance below the edge to limit the area to be hardened. These bars are 20 in. long and 4 in. wide and are hardened at the rate of 10 in. per minute. Flame hardening increased the service life of these blades 100% at an increase in cost of only 6%.

Figure 8 shows a similar setup for hardening blades 20

to 30 in. in length. In this case the flame-hardening head is one that was specially made, but it is attached to a standard welding blowpipe. Notice that the water-quenching head is attached to the back of the 2-in. wide flame-hardening head. The cutting machine is used without alterations for cutting the blade blanks out of steel plate in addition to powering the flame-hardening head.

In Fig. 9 the portable cutting machine is being used as motive power for flame hardening the rails on which a sawmill carriage operates. For this setup the standard welding blowpipe is equipped with a rhomboid head having 20 flame ports. Since the work is being done out-of-doors it is not necessary to provide means of collecting the quenching water. On this particular installation a quick-acting double shutoff valve is provided on the oxygen and acetylene lines.

It will be noted that in the setups shown in Figs. 9, 10 and 11 a counterweight is used on the cutting machine to offset the overhanging weight of the flame-hardening apparatus. This counterweight does not have to be elaborate as is apparent from the photographs. The principal advantage of using the cutting machine in these flame-hardening operations is that it provides a convenient source of power for moving the flame-hardening head at a preset uniform rate.

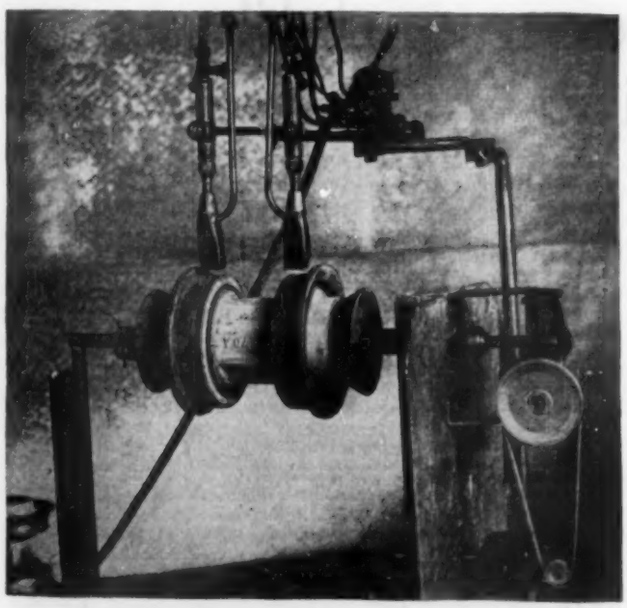


Fig. 10—This Homemade Motor-Driven Rig for Flame Hardening Tractor Rollers in Pairs Includes Two Blowpipes Fitted with Specially Made 13-Flame Heating Heads Having Integral Quenches

Progressive Hardening of Circular Parts

In the flame hardening of circular parts the blowpipe is often mounted in a fixed holder and the part to be hardened is rotated past the flame for one revolution. A setup of this type is shown in Fig. 10 for hardening pairs of single-flange tractor rollers. The rollers are mounted between conical centers on a homemade jig and rotated by a small electric motor through a reduction gear. Specially made 13-flame heads are attached to two standard welding blowpipes so that both rollers can be hardened simultaneously.

The part shown in Fig. 11 is an Army trailer hitch of

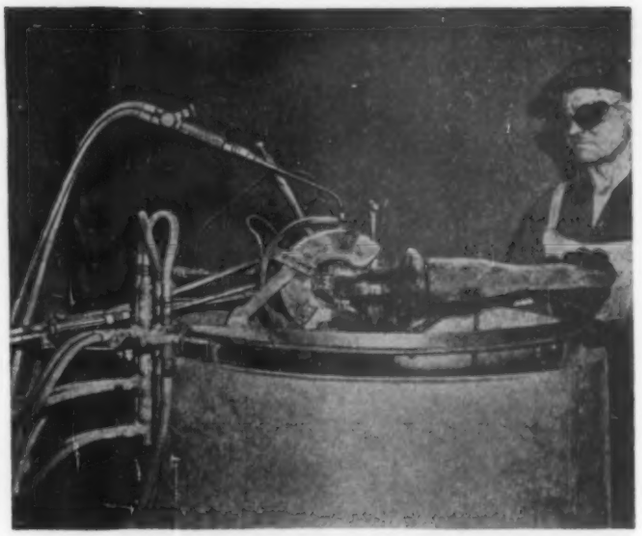


Fig. 11—Three Welding Blowpipes Supply the Mixed Gases for the Seven-Flame Heating Heads in This Simple Hand-Powered Setup for Flame Hardening the Rings on Army Trailer Hitches

S.A.E. 4140 steel, and the ring-shaped end must be hardened over an arc of 200°. The three standard seven-flame heads are supplied with oxygen and acetylene from three standard welding blowpipes. The blowpipes are fed off headers made of welded piping, and the quenching water is supplied by a spray head made from a piece of pipe. The hitch is mounted on a tapered pedestal with the outer end resting on the angle iron ring. The operator rotates the hitch steadily at a speed of about 4 in. per minute for a single pass.

Spin-Hardening Method

The converse of the progressive flame-hardening method, in which the part is usually stationary and the blowpipe moves across it, is the spin-hardening method

Fig. 12—This Flame-Hardening Rig Can Be Made from Materials That Are Available in Any Shop

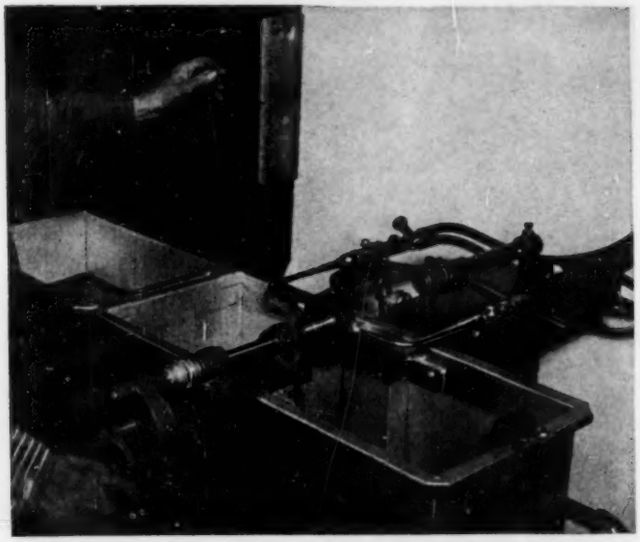


Fig. 13—The Flame-Hardening Rig Is Powered by a Hand Grinder and Can Be Adapted for Any Standard Welding Blowpipe. Here It Is Shown in Use Hardening a Small Gear by the Spin Method

in which the part is rotated for many revolutions in the flame of a stationary blowpipe. Figure 12 shows a simple hand-powered flame-hardening machine that can be made in any small shop. The motive power is supplied by a small, hand-powered grinder, heat is obtained from two standard welding blowpipes, and the rest of the parts are items that can be purchased in any hardware store, or easily made in the welding shop. This equipment can be readily adapted for spin-work hardening as shown in Fig. 13.

The examples described in this article have been selected because they indicate the wide variety of ways in which standard oxyacetylene apparatus can be combined with materials available in most shops to make a flame-hardening setup for doing a particular job. Most of these rigs look homemade and many of their designers have thought of improvements as soon as they put them in operation. The important point is that they do the job they were designed to do and that is what counts.

These examples prove that large, complicated and expensive equipment is frequently not necessary for successful flame hardening. Operators reading this article may find that one of these rigs will be satisfactory for their flame-hardening jobs or these rigs may suggest how to make one for a particular job.

The Steel Warehouse and Flame Cutting*

By Leonard J. Quetsch†

THE design and production of modern machinery and equipment could hardly have been accomplished without the development of flame cutting.

The warehouse, always on the alert for new methods that increase the sale of steel, has maintained pace with the development in equipment for flame cutting.

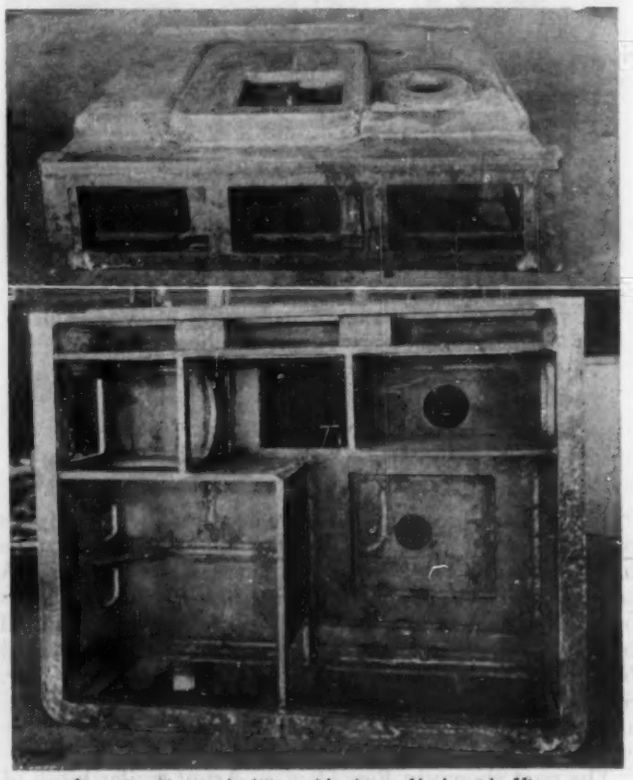
It would be well to just run through a modern warehouse. It is far from the old, cold, musty one of years ago wherein was stored steel, and, in most cases, was sold in the size and shape in which it was received. Today it is a live, vibrant plant with the noise of the friction saw and of the running of the cranes and the operating shears.

Making this trip through a modern plant is not only interesting, but educational. With the development of the new methods of flame cutting, the warehouse had to increase the thicknesses of plates carried, because now one can flame cut thickness to 12 and 14 in. So, it is not uncommon to go through plants and see plates being flame cut from the $^{3}/_{16}$-in. gage on up and through 10 in.

It is impossible for the average shop requiring a assortment of flame cutting operations to carry a suitable inventory. The warehouse, not only takes care of the particular one or two pieces that might be required for a job, but eventually takes over the production requirements.

Flame cutting is not confined to plate sections alone, but is widely used in the flame cutting of special shapes, particularly structural material. The warehouse with its modern equipment must steadily improve the knowledge of the operator, and so there is a supervisor in the Flame Cutting Department who is always instructing

Base for Vertical Milling Machine: Weight 7221 Lb.; 83 In. Long; 66 In. Wide; 25 In. High. 1-In. Plate Formed and Welded to Make Top and Side. Pad $2^{1}/_{2}$-In. Plate. Underside Plate 1 In. (See Photo Below)



Base for Vertical Milling Machine, Underside View

* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October 1945.
† First Vice-Pres., A. M. Castle & Co.

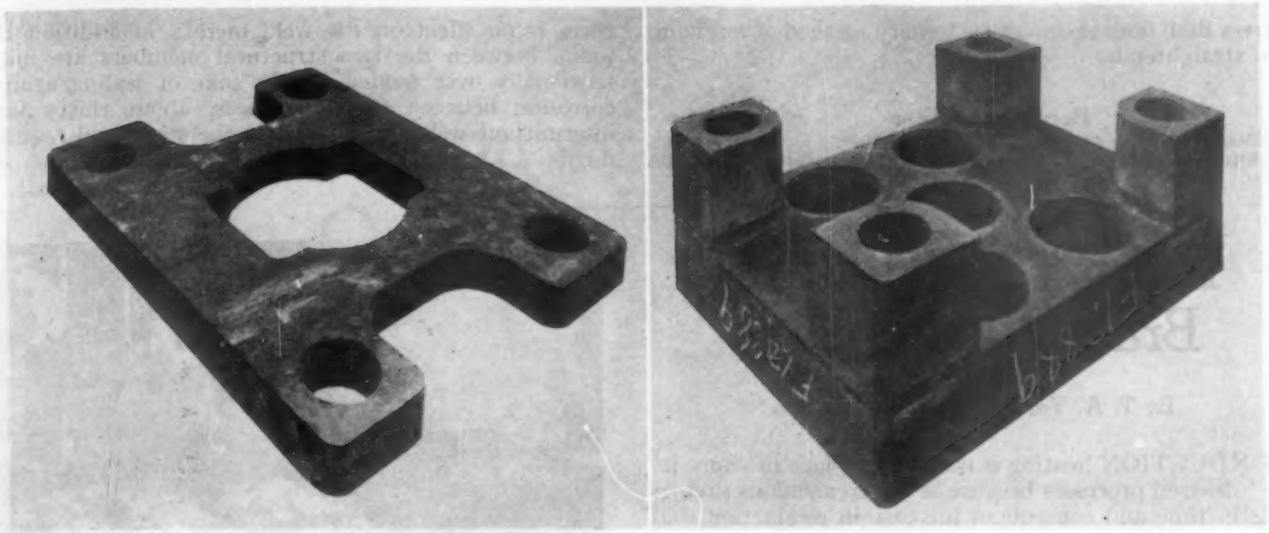


Plate $3^1/_4$ x 30 x 38; 1 Hole $14^1/_2$ x 16; 4 Holes 5 In. Diam.

men, and, after a number of years, these men are moved up and become the operators of the machines that do the intricate work. The best of equipment in the hands of incompetent or inexperienced operators is of no value. Within the limit of the tolerance of the machines the demands of the fabricator must be met, and so the steel warehouse engineer is often called upon to assist in the design of new equipment involving flame cutting.

The breakdown of some production machinery part occurs and then it is customary that a drawing be made of the finished part, and, when this reaches the steel warehouse, there the template maker makes a full size template and the operator manually guides the tracing device that controls the travel of the torch or torches. The tracing device itself is set at a constant speed for the thickness required, and the operator cannot advance nor retard the speed so that a good, clean cut is assured. It is only natural, however, that when this hand tracing is done the tolerances must be more liberal than when the magnetic head is used.

For production requirements where each piece is to be duplicated the steel warehouse uses magnetic head templates. This type of template is usually cut from $^3/_{16}$- or $^1/_4$-in. steel plate and then a sample is submitted for final checking. In this magnetic tracing over a steel template one is assured that all parts will be exactly duplicated.

During the recent war effort the warehouses point with particular pride to their performances in assisting so many of their customers and are prepared to continue to furnish flame-cut products in the reconversion period.

We are showing a few examples of flame cutting, and I have deliberately picked out the photographs of the thicker sections because you can obtain an idea of the finished service with the assurance of a like condition in thinner sections. Two of these photos show the combination of flame cutting, forming and welding. The others are simply flame-cut pieces, but do demonstrate what can be procured from your average steel warehouse operating a Flame Cutting Department. For the engineer it shows flexibility of design.

The machine with the proper tip, correct pressure and right speed, topped with a competent operator assures a perfect finished piece.

Discussion Paper on "Welded Gas Holders with Panel Type Lifts"*

By Geo. F. Wolfe†

MR. KRAUS and The Stacey Bros. Gas Construction Company are to be congratulated for their willingness to depart from conventional designs based on fabrication by riveting and to develop a design properly adaptable to welding.

The preparation of plate edges by burning both in shop and field and the ability to ship considerable plate tonnage directly from the rolling mill to the erection site are definitely steps in the right direction. The application of automatic welding to the composite columns in the shop is noted and one is inclined to wonder whether the use of automatic equipment has been considered for the floor and crown plating in the final erection. This usage would of necessity be limited to good weather conditions as considerable difficulty is experienced with outdoor automatic welded joints due to moisture and corrosion. It is to be hoped that the manufacturers of such equipment will give more study to outdoor applications and develop a flux which will be less sensitive to impurities thus enabling us to make automatic welds under the same conditions that hand welds are made.

The use of a water spray directed against the underside of the members automatically welded to reduce distortion raises the question as to whether this accelerated cooling has any deleterious effect on the weld metal. If the control of distortion by a water spray has no injurious effect, it undoubtedly provides a greater uniformity of residual

* Annual Meeting Paper presented by Mr. Rudolph Kraus of The Stacey Bros. Gas Construction Company and published in the Dec. 1945 issue THE WELDING JOURNAL.

† Welding Consultant, Engineering Works Division of Dravo Corporation.

stress than does the more customary method of mechanical straightening.

Reply by Author

Our tests showed that in this particular application there is no effect on the weld metal; in addition the joints between the two structural members are unintentionally over welded for the sake of sealing against corrosion between faying surfaces, about thirty feet; intermittant welds would satisfy the structural requirements

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Induction Heating Brazes Tool Tips

By T. A. Vernor* and E. F. Adams*

INDUCTION heating is making its place in many industrial processes because of the tremendous savings in time and consequent increase in production that is gained by its use. A recent installation at the Reed Roller Bit Co. of Houston, Texas, brazes alloy tool tips onto single point tools in a fraction of the time formerly required with acetylene gas torches.

A great number of tools are required at the plant, since the stock hardness of the product is approximately 350 Brinell and the tools break or dull from wear. When acetylene torches were used, the tool tip was overheated and several minutes were required to braze each piece. Tool tips can now be brazed on a $1^1/_2 \times 1^1/_2$-in. tool, which is the largest used, in about 30 sec., using induction heating. Not only is the brazing job speeded up, but the life of the tool is improved since the tungsten tip and the soft steel shank are heated at different rates and the tip does not reach the same temperature as the shank. This is evident as the power input to a magnetic material is many times greater than to a nonmagnetic material with the same flux density. Most of the heat put into the tungsten tip is by conduction from the steel tool through the silver solder.

As only about one inch of the tool is in the coil, all of the power is concentrated in a small volume in a very short time. This brings the temperature of the shank to about 1400° F. in 30 sec. or less on one end of the tool—depending on the size of the shank—and leaves the other end cool enough to handle with the bare hands.

The work coil for this job was designed to handle several sizes of tools without adjusting the R. F. generator or changing the work coils. This was accomplished by designing two coils and connecting them in series. One coil consists of six turns of $^1/_8$-in. copper tubing 2 × 2 in. on the inside square. The other coil also of six turns is $1^1/_2 \times 2$ in. on the inside square. With both of these coils connected to the generator in series, it was found that all sizes of tools could be heated. This method enables the operator to handle several sizes of tools without first sorting them by sizes, and therefore increases the over-all flexibility.

Fig. 1—Brazing a Tungsten Alloy Tool Tip on a $1^1/_2$ x $1^1/_2$-in. Tool Shank by Use of High Frequency Induction Heat. Two Coils of Different Size Are Connected in Series, Thus Making the Sorting of the Shanks Unnecessary

Fig. 2—Brazing Tips to Single Point Tool Shanks and Removing of Those That Have Been Dulled by Wear Is Done in Thirty Seconds or Less with a Standard 10Kw, 450Kc R.F. Generator. Joining Is Done on a Production Basis Since it Is Unnecessary to Sort the Various Sized Shanks

One safety feature of the Tuned Plate-Coupled Grid oscillator circuit that is used in the generator is the grounding of one side of the work coil thus putting it at a comparatively low voltage above ground. This is possible since most of the voltage is across the tank coil.

The R. F. generator used is a standard 10-kw., 450-kc. set. The power supply is 440 volts, 3 phase, 60 cycle. Control is by means of a "start-stop" button mounted on the face of the cabinet; additional remote control stations can be provided where required. On production work such as this where a definite time-heat cycle can be predetermined, the automatic timer de-energizes the unit after a predetermined time has elapsed. Protection to the generator is obtained by magnetic type overcurrent relays in the plate circuit of the rectifier and the grid circuit of the oscillator tube. The main line circuit breaker has thermal and instantaneous magnetic overload protection, and the control circuits are fused. The grid-controlled 3-phase rectifier in this unit provides a flexible means for power output control to the work.

After installation and tune-up, an inexperienced operator had no difficulty working with the generator and was soon very proficient in its use, both for brazing on new tips and removing those dulled by wear. As a result, the plant has experienced no tool shortage and one bottleneck in production was broken.

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* Westinghouse Electric Corp., Houston, Texas.

The Application of Pressure Welding to Overland Pipe Lines*

By E. P. Jones†

Abstract

This paper covers the development of the pressure welding process as applied to the joining of overland pipe.

Briefly, the pressure welding process consists in butting together, under a predetermined pressure, two members to be welded, heating their juncture with oxy-acetylene flames to a temperature within the range of 2100–2500° F., and upsetting to a predetermined degree. The process is generally mechanized so as to be semiautomatic in operation. As such, it has been used in a widely diversified range of applications in industry, including railroad rails, oil well tool joints, propane tanks, aircraft landing gear, etc.

In the recent past, several articles[1] have been published in technical magazines describing the engineering aspects of the varied applications. A thorough discussion of the theoretical phases of the pressure welding process were dealt with in last year's Comfort A. Adáms' Lecture.[2] It is the purpose of this paper to present the history and development of equipment, and the technique for adapting this oxy-acetylene process to pipe-line right-of-way conditions.

Discussion

IN December 1940, the El Paso Natural Gas Co. started work on the first pressure welding clamp for overland pipe. This machine was constructed to weld 6⅝-in. O.D. line pipe. In March 1941, the initial pipe line was welded. This was 4½ miles in length; 6⅝ in. O.D. with 0.203 in. wall thickness. All equipment was carried on a truck, and the welding clamp was suspended over the work from a stationary boom rigged on the side of the truck.

In the latter part of 1941, another clamp was built to handle 10- and 12-in. pipe. Twenty-seven miles of 10¾-in. O.D. by 0.203-in. wall thickness pipe was welded between Douglas and Benson, Ariz. This established the process with the El Paso Natural Gas Co., and additional machines were built to handle their pipe-line work.

By midyear of 1942, it was decided to introduce pressure welding into the pipeline construction field on a competitive basis with other welding processes. In August 1942, an 8⅝-in. O.D. and 10¾-in. O.D. pipe line was pressure welded for The Texas Co. between Dallas and a point near Armstrong, Okla. Since that time, oil, natural gas, water, helium and propane pipe lines have been welded in sizes from 2 in. through 24 in. O.D. At the present time some 1500 miles of pressure-welded pipe lines are in operation in the United States and Mexico.

Clamp Development

In order to be practical for right-of-way work, it was necessary for the pressure welding equipment to be easily portable over any type of terrain. Also, in order to compete with existing methods of welding, the machine must turn out large numbers of welds each day. It was decided that the most rapid and safe method of transporting the welding machine was to suspend it from the side boom of the standard pipeline track-type tractor on the end of a steel cable. By hinging the clamp from the top, in clamshell fashion, it could be lowered into place over the joint to be welded with little loss of time. Between welds the machine could be lifted free and transported in the raised, open condition to the next joint.

On line pipe up to 8 in. O.D. a simple, lightweight clamp was used, because in the smaller sizes of pipe the manufacturing tolerances provided little variation in dimensions. These clamps were provided with fixed gripping dogs, which were forced against the outside surface of the pipe by hydraulic gripping cylinders located on the lower frame of the machine.

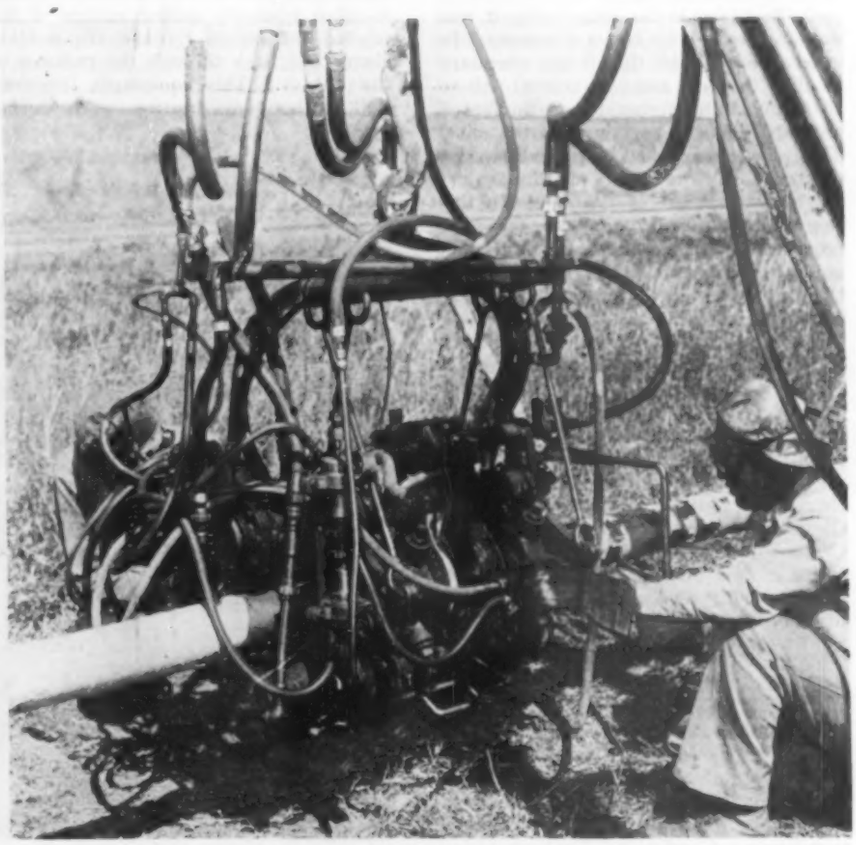

Fig. 1—Photograph of Pressure Welding Equipment in Use on 4½-In. O.D. Propane Pipe Line for Dow Chemical Co.

* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October, 1945.

† Manager, Pressure Weld Co., Houston, Tex.

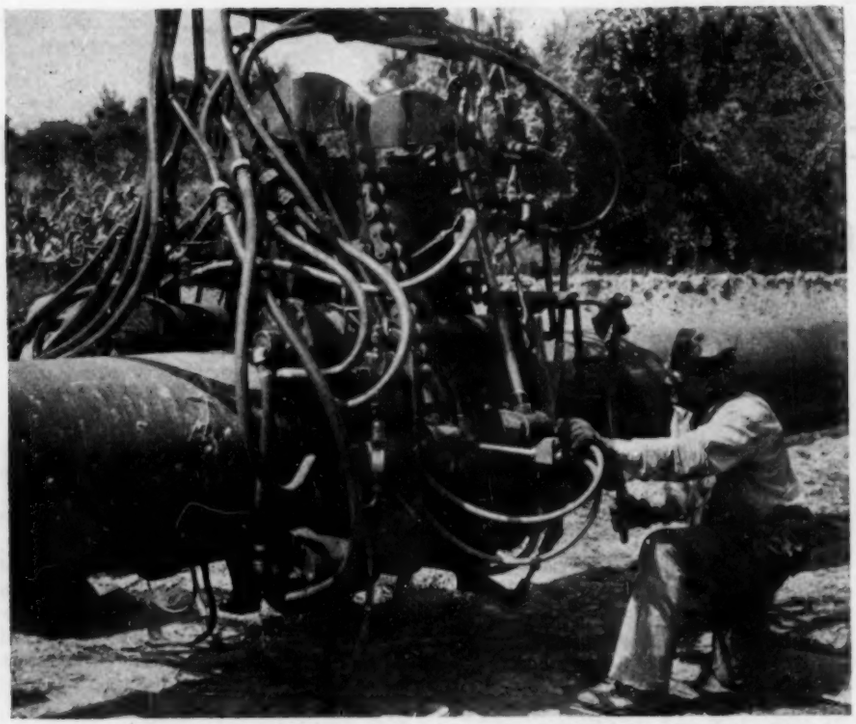

Fig. 2—Photograph Showing Pressure Weld Machine in Operation on 24-In. O.D. Natural Gas Pipe Line for Tennessee Gas & Transmission Co.

End pressure to produce upsetting during welding was provided by hydraulic cylinders at the ends of two pull rods which ran the length of the machine. This type of clamp is shown in Fig. 1.

On line pipe in the larger sizes it was necessary to provide better alignment. In order to accomplish this, it was necessary to align the pipe along its central axis so that any outage would be distributed around the entire periphery of the joint. This was accomplished by providing gripping dogs which moved in radially against the outside surface of the pipe. In this case the hydraulic gripping cylinders were mounted at the top of the machine and applied their force through rods and roller chains connected to the gripping mechanism. Four hydraulic cylinders, operating through pull rods, provided the end force for welding on this type of clamp, shown in Fig. 2.

Both types of clamps described were provided with water cooling to all the essential parts. Hardened alloy steel gripping dogs were machined to the contour of the outside surface of the pipe. Only a nominal amount of penetration into the pipe wall is produced by their gripping action. This was achieved after experimenting with several types of gripping tooth designs.

Hydraulic Controls

A standard hydraulic pump provides pressure to the hydraulic cylinders of the welding clamps. The pump is mounted on the side of the tractor and is driven by a roller chain from the tail shaft of the tractor's power take-off unit.

A hydraulic manifold is mounted within easy reach of the tractor driver, who operates the control valves during the welding operation. This arrangement is shown in Fig. 3.

A cooling water circulating pump is also driven from the tractor's tail shaft. Water is taken from the cooling system of the tractor and forced through the welding clamp and back through the radiator of the tractor. This equipment functions well, without overheating, even during summer heat in semidesert areas of the Southwest.

Oxyacetylene Equipment

Special oxyacetylene heating heads were developed for welding line pipe. Small diameter flame ports were closely spaced so that the heat distribution at the weld joint approached that of a continuous ribbon flame. Extra precautions were taken to provide adequate water cooling, because of the intense localized heat. It was found necessary to provide water-cooled tubular trusses along the backs of the heads used on large diameter pipe to insure their retaining their true shape under the influence of the intense heat.

Mixed oxygen and acetylene gases were supplied to the heating heads from standard machine type blowpipes. Quick-acting shut-off valves were used for manually controlling gas flow.

In order to transport the acetylene generator and oxygen cylinders, trailers were designed which were hooked to the tow bars of the tractors. These were constructed to operate under all right-of-way conditions. Single-type pneumatic wheels were used so that, on soft rights-of-way, the trailer would settle on to its scow-like chasis and not bog down. Figure 4 shows this type trailer in use.

Special 150- and 300-lb. capacity portable generators were used to supply the acetylene gas for welding. A standard oxygen manifold setup was used to handle the oxygen supply. An additional oxygen cylinder was used for cutting operations.

Grinding Equipment

Early work with the pressure welding process established the use of the plain butt type of weld joint in all applications. This required that the pipe ends be ma-

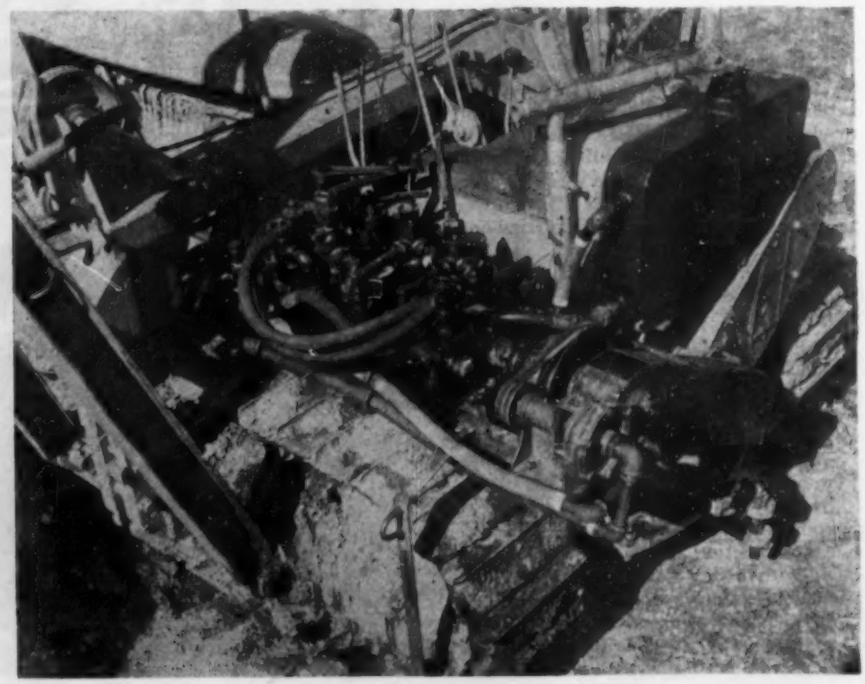

Fig. 3—Photograph Showing the Hydraulic Controls Mounted on Side of Pressure Weld Tractor Within Reach of Tractor Operator

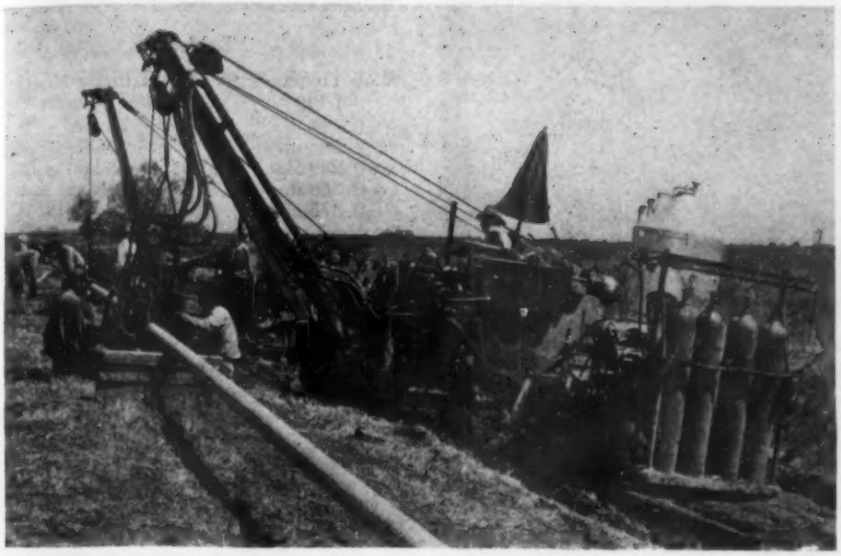

Fig. 4—Photograph Showing Pressure Welding Equipment in Use on Soft Right-of-Way. Specially Designed Trailer Settles on Scow Chassis So That It Floats Instead of Bogging Down

Fig. 7—Photograph of a Pressure Weld in 12¾-In. O.D. by 0.250 In. Wall Thickness Pipe

chined square with the axis of the pipe. However, mill tolerances and the hand grinding technique used to clean the ends on the right-of-way resulted in nonuniform surfaces. This was serious because any reverse angle, where the joint was open to the inside of the pipe, allowed the atmosphere to contact the edges to be welded, resulting in the formation of an oxide film, and thus lowered the weld quality. To overcome any such tendency, experiments were made with a small outward bevel forming a narrow vee toward the flames. This proved successful. Mechanical equipment was next developed to position and rotate emery disks or cup-shaped grinding wheels at the proper bevel angle against the pipe. A typical grinding jig is shown in Fig. 5.

Electric motor or compressed air grinding heads are used to drive the grinding jigs. Pipe ends can be polished in a matter of a minute or less, at a few cents cost. The grinding crew is positioned directly ahead of the welding crew so that little time elapses between the grinding and welding operations.

The Welding Cycle

The technique for pressure welding on the pipe line right-of-way has developed to the point where rapid progress can be made with the bulkiest of welding equipment. The pipe is supported on wooden skids about 4 ft. long and 4 x 6 in. in cross section, stacked in the same manner used for manual welding. Sufficient room is left to permit the clamp to be latched beneath the pipe. The new length of pipe to be welded is lifted at its midpoint by a tractor assigned to line-up operations, and moved into alignment with the end of the previously welded string. A wedge-shaped "Jack-board" is forced under the pipe from each side, about 6 ft. from the joint, to support it at the correct height in alignment with the other pipe end. The clamp is then lowered into position and latched.

The operators move the clamp horizontally until the edges are in approximate alignment. Then the line-up tractor raises or lowers the far end of the pipe to bring the joint into close vertical alignment. This is done in a matter of seconds. Then the pipe is gripped rigidly in the machine and skids are placed under the pipe about 6 ft. from its far end. This allows the line-up tractor to release the pipe and move off to obtain a new length, while the welding is in progress. Figure 6 shows the line-up crew aligning pipe in the pressure welding machine. On small diameter pipe the latching operations and moving between joints have been accomplished in the short time of 17 sec. On large diameter pipe this time is lengthened by reason of the weights being handled.

When alignment is completed and the pipe gripped in the welding machine, the initial end pressure is applied to force the pipe ends together. The heating head is next positioned manually in alignment

Fig. 5—Grinding Jig in Use on 24-In. O.D. Line Pipe

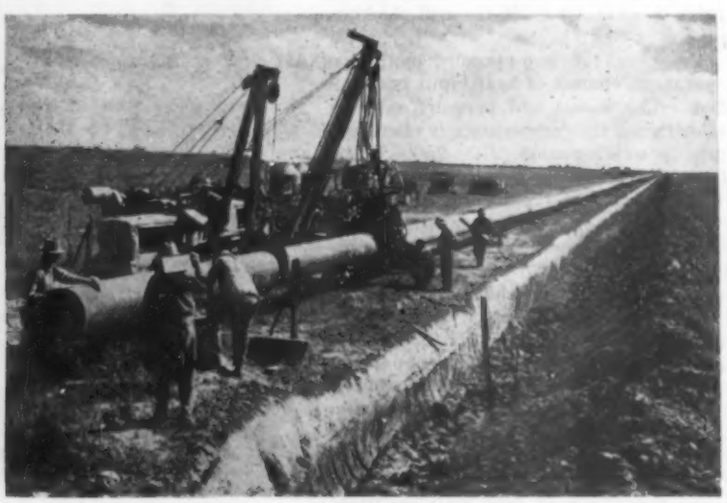

Fig. 6—Photograph Showing Line-Up Crew Aligning 24-In. O.D. Pipe in the Pressure Welding Clamp

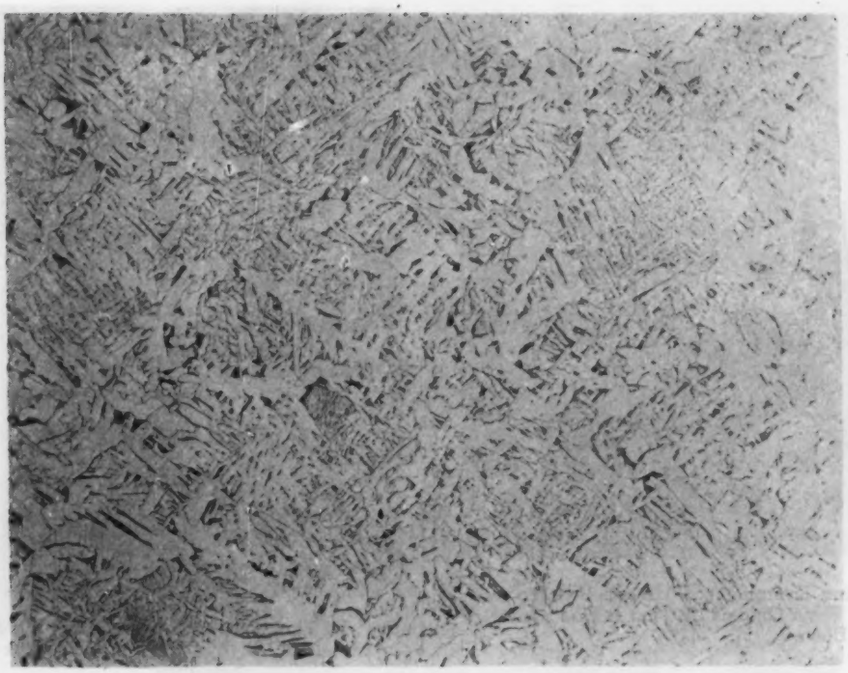

Fig. 8—Photomicrograph at 100 Diameters of a Typical Pressure Weld in Line Pipe. The Original Weld Interface Runs Horizontally Through the Section Shown

with the groove formed by the pipe ends, and the gases ignited. The flames are quickly checked to assure proper adjustment. Heating is continued until the joint is brought to welding temperature. At this point, the final or upsetting pressure is applied. An electric limit switch operates a signal which warns the tractor operator when sufficient upset or gather has been obtained. He immediately reverses the flow of oil to the hydraulic cylinders, retracting the welding clamp.

During the latter part of the weld cycle the heating flames are reciprocated a short distance on either side of the weld interface in order to distribute welding heat uniformly throughout the zone and to lightly fuse the external upset. This eliminates all traces of the original edges of the pipe ends to produce a uniform-appearing weld surface. Figure 7 is a photograph of a typical pressure weld in 12¾ in. O.D. by 0.250-in. wall thickness pipe.

By using the two-pressure method of operation, control of heat input is simplified. The initial end pressure is maintained until the temperature is raised well into the welding range (2100–2500° F.) before the upsetting pressure is applied. Thus, danger of premature upsetting is minimized before the material at the inside of the pipe becomes properly heated. Experience has shown that the process has sufficient latitude so that this procedure can be depended upon for consistent results.

By basing the end point of the operation upon obtaining a predetermined amount of upset or gather, rather than upon time or surface temperature, more positive control is obtained. Thus, any small variations in the material to be welded, such as slight differences in pipe wall thickness, will be compensated for. However, the checking of many welds in the field with a stop watch reveals welding times consistent to within 1 or 2 sec.

The welding times for various pipe wall thicknesses are as shown in the following table:

Table 1

Wall Thickness of Pipe	Approximate Heating Time Required
0.187 in.	45 sec.
0.203 in.	50 sec.
0.238 in.	55 sec.
0.250 in.	60 sec.
0.375 in.	90 sec.

Metal Compositions

All grades and compositions of line pipe are readily pressure welded. These are, in general, steels containing carbon and manganese as the principal alloying elements. The manganese varies upward to approximately 1%, depending upon the grade classification. The carbon range of these steels usually does not exceed 0.30%.

High strength drill pipe and casing pipe have been pressure welded both experimentally and in short pipe lines. In the latter case, the drill pipe and casing pipe was purchased as used material, under war conditions.

Weld Characteristics

There is no "cast structure" characteristic of fusion welds. The grains in the metallic structure of the weld zone which form on normal cooling are ordinarily larger than similar grains in the base metal, this being the result of grain growth at the welding temperature. This grain structure can be easily refined, if desired, by normalizing, but the properties of the metal in the weld zone in line pipe have not been altered sufficiently to warrant such a treatment.

Figure 8 shows a photomicrograph at 100 diameters of the material at the original interface of the weld joint. The weld runs horizontally through the center of the section shown. Figure 9 was taken at 400 diameters from the same section. The weld again runs horizontally through the center of the section shown. Recrystallization has been complete so that the indi-

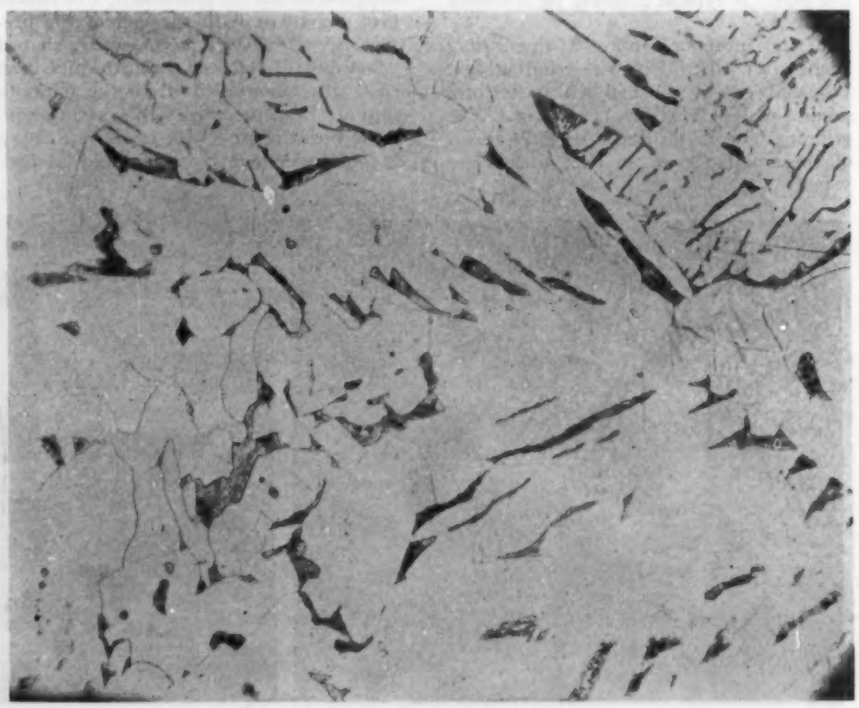

Fig. 9—Photomicrograph at 400 Diameters of the Same Section as Shown in Fig. 8. The Weld Runs Horizontally through the Center of the Section Shown

cations of a weld are practically indistinguishable.

As welded, the weld joint usually has more ductility than a similar joint made by the fusion welding process because the entire joint is heated at once; therefore, there is practically no localized, rapid cooling, and the cooling rate of adjoining material is retarded.

Properly made field pressure welds in line pipe will pass the usual tensile, free bend and root bend tests. In one particular instance some 4700 physical tests were made during the construction of a pipe line. The average tensile strength recorded exceeded 75,000 psi. on reduced tensile specimens and over 25% elongation across 2-in. centers, transverse to the weld zone.

The photograph in Fig. 10 shows a typical cross section of a pressure weld in 16-in. O.D. by 0.250-in. wall thickness pipe. The photomicrographs, Figs. 8 and 9, were taken from this weld. The specimen has been etched to show the changes in grain structure produced by the welding operation.

It will be noted that the upset produced on the inside of the pipe is smooth and rounded. Little restriction in flow results. Proof is presented by the many miles of pressure-welded lines delivering their products at, or in excess of, designed capacity.

Another important factor is that the "go-devils" forced through the pipe line for cleaning purposes are not damaged, as there are no protrusions of metal or "icicles," which often extend into the pipe with manual types of welding.

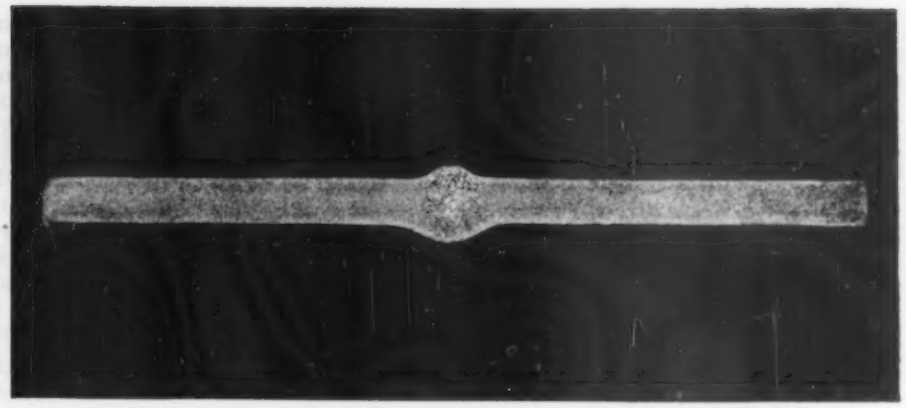

Fig. 10—Photograph of an Etched Cross Section from a Pressure Weld in 16-In. O.D. by 0.250-In. Wall Thickness Pipe

General

This new oxyacetylene process has been tested under conditions considered to be extremes in pipe line and oil field construction. Pipe lines have been laid in swamps and rice fields of Louisiana and East Texas. It has been applied on rights-of-way in West Texas where every foot of the trench used for burying the pipe had to be blasted. It safely negotiated mountains of Pennsylvania and Arizona, and the prairies of Kansas and the Texas Panhandle. These illustrations serve to prove that the process is universal in nature and can be used wherever pipe-line construction is attempted.

Two pipe lines recently constructed serve to illustrate the quality of welding performed. Approximately 130 miles of helium pipe line were constructed to transport this lightweight gas between refineries and loading plants in New Mexico and Texas. Tests prior to the welding of this line showed that ordinary pinholes in fusion welds would leak appreciable quantities of this monatomic gas, which has a density so low that over three times more would be lost than with natural gas under similar conditions. When completed, this line was tested, found tight, and placed in operation at approximately 2500 psi.

The second illustration is a complete gathering and injection system of 3-, 4- and 6-in. pipe for a recycling plant. High-strength pipe was used on this project; and on completion, a 3400 psi. cold water test was placed on the 3- and 4-in., and 4000 psi. on the 6-in. pipe for a period of 18 hr., without leaks or pressure drop. The above work was accomplished with the standard field procedure, without resorting to special precautions and techniques necessary with other processes on like material.

Summary

The pressure welding process, as developed to date, has proved a practical, as well as versatile method for joining overland pipe lines. Perhaps its most outstanding feature is the production of large numbers of welds in which the quality is uniform throughout the series. It is an established fact that the fatigue factor in manual welding of line pipe in the field is considerable, and shows up as lowered efficiency toward the end of the day's work. By transferring the major load to the semiautomatic machine operation, this factor has been greatly minimized.

It is believed that the pressure welding process has established itself in the pipe-line construction field. Its continued use will serve as justification for this assumption.

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2. Presented at the Twenty-Fifth Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 16 to 19, 1944. Kinzel, A. B., Vice-President, The Electro Metallurgical Co., and Chief Metallurgist, Union Carbide and Carbon Res. Labs., Inc., N. Y.

Discussion on "Shop Notes on Welding Stainless Steel"*

By J. B. Arthur†

WE HAVE read the annual paper presented in the August 1945 issue of THE WELDING JOURNAL concerning the welding of stainless steel.

In Part IV, title "Selection of Sizes and Quantities of Electrodes," we note the following statement: "Coated electrodes must be kept dry. This can be obtained by heating rod storage room or cabinet to about 80 or 90° F. Poor welds result in a damp coating. Damp coating will crack and drop off while welding and the bare electrode must then be discarded."

At Calship we have completed a minimum of 15,000 tests upon electrode variables affecting performance efficiency of electrodes. The actual number of variables investigated to date is 37. These tests were made on both a production and laboratory basis and cover mild steel and alloy coated electrodes. One of the variables very thoroughly investigated was moisture contained in the coating of electrodes. Results of these tests are in process of being worked up into a comprehensive paper which we will present for consideration at an early date.

* Paper by V. J. Shanahan published in the August 1945 issue of THE WELDING JOURNAL.

† Testing Engineer, California Shipbuilding Corp.

Inasmuch as we take exception to the author's statement concerning the effect of moisture in electrode coating, we would like to check our data and results on it; therefore, we would appreciate receiving answers to the following questions from the author concerning his statement as above:

1. Is the statement based on circumstantial or absolute scientific evidence?
2. What are the specific properties of the resulting weld which make it undesirable due to moisture content?
3. What is ideal moisture content of coated electrode of the 18–8 type?
4. What moisture content is ordinarily present in the electrodes as received from the dealer or manufacturer?
5. Under normal storage conditions without artificial heat, etc., how much does the moisture content in these electrodes vary between storage and use? And what is the range of variation?
6. In case of poor operating efficiency on electrodes of this type, does drying out these electrodes actually produce more desirable results in the one case versus the other? And if so, in what per cent of the cases?

It has been our experience that poor welding results from electrodes have too often been laid at the door of excessive moisture. It would appear from our results that one of the primary considerations in the performance of any electrode is the state of the bond between the core wire and flux. If the bond is poor the electrode performs unsatisfactorily and produces questionable results. If the bonding is satisfactory (that is, the manufacturing process has been controlled correctly), then moisture would seem to definitely improve, or at the least, not affect the quality of the results both from the standpoint of the operator and of the physical properties of the completed weld.

It would further appear that inasmuch as the coating contains in most cases hydrated salts and metallic oxides, and they are ordinarily in a natural state of equilibrium with moisture, the coating requires moisture in order to be stabilized and thus give uniform results.

On the basis of results obtained from our tests, we feel that a reasonable moisture presence is not a critical condition which will cause trouble. We further feel that the complete moisture story is told the minute the electrode comes off the drying line at the manufacturing plant.

Discussions on "The Heliarc Welding Process as Applied in the Aircraft Industry"*

By F. R. Shanley†

MR. PIPER has presented some interesting facts about the Heliarc Welding Process, which is undoubtedly a valuable method of welding. The principle of shielding by means of an inert gas is, of course, the most important feature of the process. Recent developments indicate that this principle may find even wider applications, such as in flash welding.

To a reader not acquainted with aircraft production in various plants some of Mr. Piper's comments might be slightly misleading. The title of the paper, together with the opening statement, gives the impression that in the aircraft industry welding is the most commonly used process for joining metals and that the Heliarc method is widely used. Lack of any reference to the corrosion susceptibility of the high-strength aluminum alloys, after arc welding, also seems questionable. The charts of Fig. 12, together with the statement that "satisfactory Heliarc welds have been produced on . . . 24S and 75S wrought sheet materials" would indicate that Heliarc welding can be successfully used for these materials.

Actually, the most recent trends (at Lockheed) appear to be toward less welding, in general. This can only be explained by the difficulty of maintaining adequate control, which in turn is due to the difficulty of inspecting the interior of a weld. This is particularly true of spot welding and has recently become an important factor in the flash welding of large parts. For light alloys, the most commonly used joining process continues to be riveting.

Neither arc nor gas welding of the high-strength aluminum alloys (24S and 75S) is satisfactory, because of the reduced corrosion resistance of the heat-affected zone. Heliarc welding is no exception and none of these processes is being used in fabricating primary structure from aluminum alloy. Heliarc welding has been successfully used for structural magnesium alloys, but it cannot be said that this is a common method of fabrication in the aircraft industry.

The development of a high-strength, low-density alloy which can be arc or gas welded without appreciable loss of strength, ductility or corrosion resistance is a worthwhile research objective and seems to deserve more attention than it has received in the past.

* * *

By C. T. Fallon‡

Mr. Piper is to be complimented on an excellent article, covering the various applications of the Heliarc Welding Process as applied in the aircraft industry. Incidentally, our company has done a considerable amount of research and experimentation in the use of high frequency stabilization, and it will probably be of interest to learn that the use of high frequency current superimposed on the welding current operates equally as well on either direct current or alternating current. The following advantages are gained in the use of high frequency superimposed current upon the welding current.

1. Improved arc stability and a greater arc length throughout the entire current range.
2. Eliminates the necessity of striking the arc and therefore provides for greater flexibility.
3. Allows the use of tungsten electrodes on stainless, monel, Hastelloy, Everdur, as well as ferrous and other nonferrous alloys.

* Paper by T. E. Piper, Northrop Aircraft, Inc., published in the October issue of THE WELDING JOURNAL.

† Engineering Research Division Engineer, Lockheed Aircraft Corp.

‡ Process Service Supervisor, The Linde Air Products Co.

Welded Design as Applied to Lightweight Army and Navy Structures*

By H. A. Oldenkampt

THE purpose of this paper is to discuss the advantages and disadvantages of welding as applied to lightweight Army and Navy Structures. Comparison will be made with other kinds of fabrication, and the paper will be concluded with a description of some of the equipment which was produced.

The designer of Army and Navy structures is faced with design considerations which almost preclude the type of fabrication which is to be utilized. These design considerations include the availability of certain types of labor, weight requirements, ultimate use of the structure, electrical considerations, transportability, blast requirements and safety factor. The strength and safety factor requirements have almost invariably turned out to be functions of the weight which is usually established by the Armed Forces, before the piece of equipment is designed. Obviously the design weight is as low as possible, and as a result it is no exaggeration to say that we have had to work very close to a one to one safety factor.

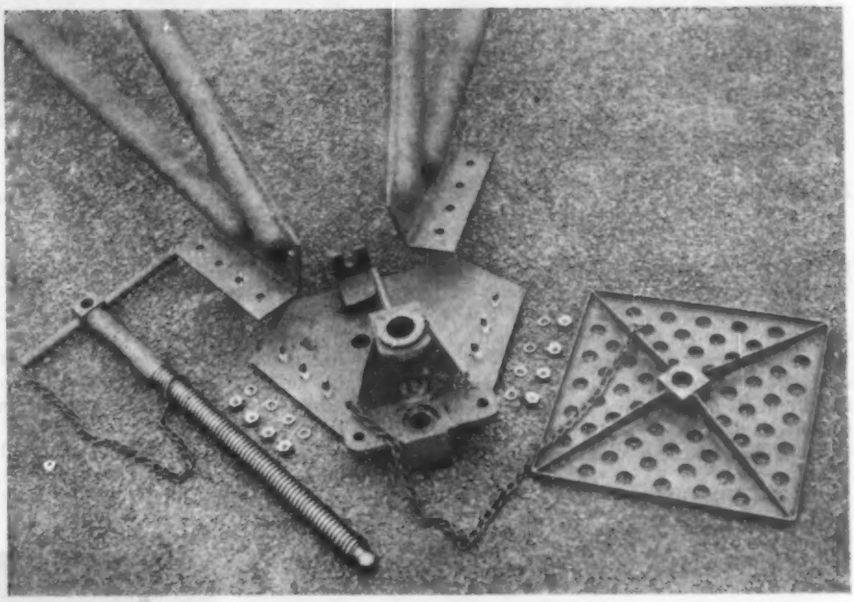

Fig. 2—Parts of Jack Screw Assembly Showing Tube Terminations

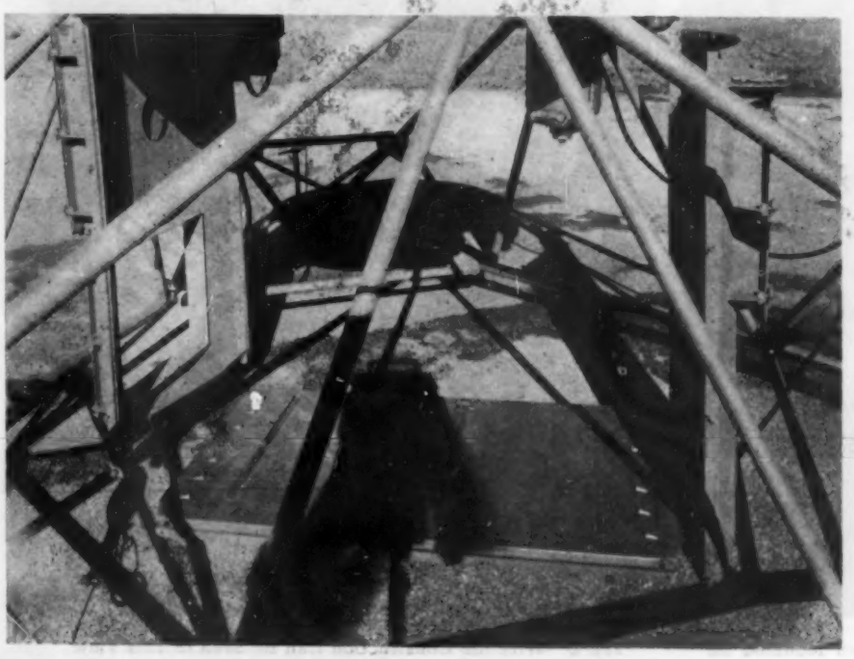

Fig. 1—Portion of Tubular Outrigger Assembly

With regard to transportability the designer has had to contend with methods of handling equipment from one operating point to another. Any or all modes of travel must be considered including "brute" man-power, mule-back, airplane, truck, etc. The usual desire is that the equipment be broken down into packages of 50 lb. or less. However, packages up to 200 lb. are acceptable. Hand-carrying means employing several men must be provided on packages weighing in excess of 200 lb. Transporting by aircraft is now commonplace and packages must be designed of size and weight adequate for various types of planes.

The ultimate geographical use of the equipment very often determines the type of fabrication and the type of material used. In recent months, because of the activity in the Pacific area, all equipment including both Army and Navy structures has been designed for salt water use. However, more emphasis is placed on the use of corrosion-resistant materials for Navy equipment because of the more direct ex-

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* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October 1945.

† The Warner & Swasey Co., Cleveland, Ohio

Fig. 3—Field Installation of All-Welded Tubular Support

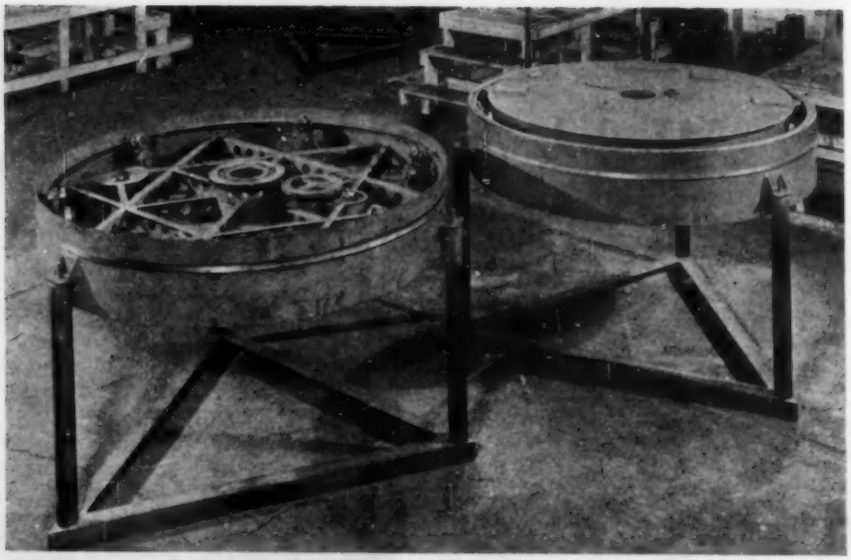

Fig. 4—View to the Left Shows Pedestal with Turn Table Removed Showing "Merry-go-round" Roller Construction and Reinforced Sheet Steel. View to the Right Shows Turn Table in Place

posure to salt water and because of the longer life expectancy of the equipment.

With certain types of Army and Navy equipment, the type of construction used was determined to a large extent by the electrical requirements. These electrical requirements in many instances determine the mechanical shape and often were the starting point of the mechanical designer's work.

Navy equipment, because of the proximity to large guns must be designed to withstand blast, sometimes as high as 20 lb. per square inch. The mechanical engineer is faced with the problem of designing an extremely light structure which, on the other hand, must be heavy and strong enough to withstand blast. The procedure is to use the best engineering judgment available in making the design, build a model and then blast test it. Redesign is often necessary after the blast testing.

The design considerations outlined above have in most cases of our experience pointed to arc welding as being the most advantageous method of construction. In fact, some of the structures mentioned could not have been built but for arc welding.

There are some exceptions in which arc welding did not prove satisfactory. Doubtless a suitable arc-welded design could have been worked out to an advantage for these exceptions; however, the expedient seemed to be to choose another method of fabrication. In the fabrication of extremely light tubular structures, our experience has shown that acetylene welding is easier and does a nicer looking job. This

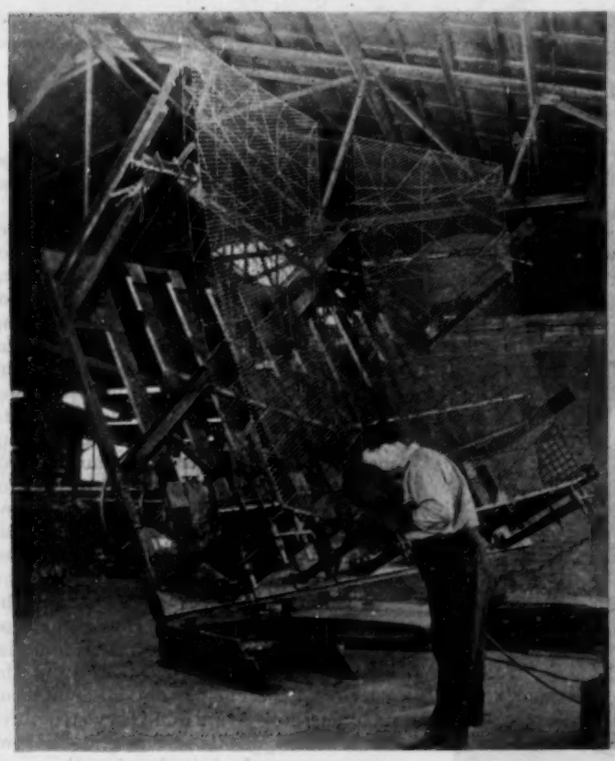

Fig. 5—Portion of Expanded Metal Screen Mounted on Large Tilting Fixture

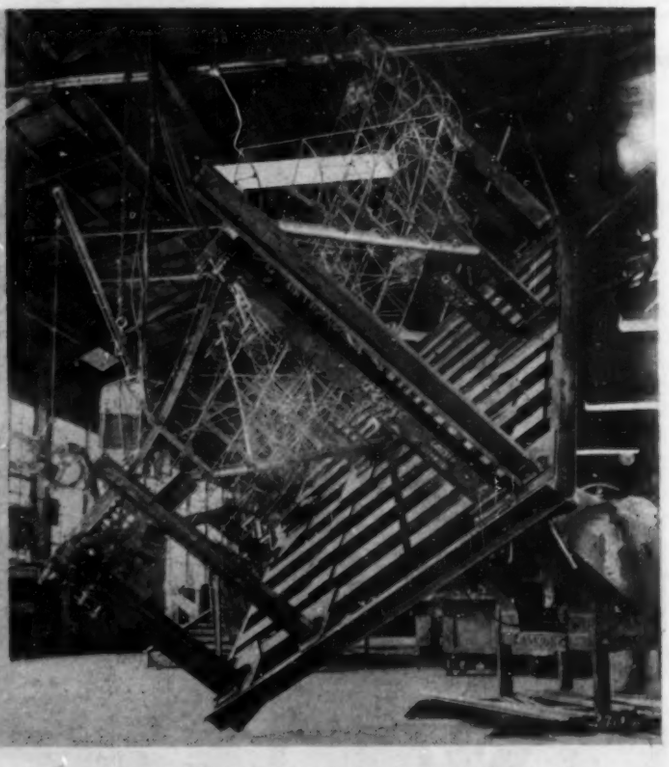

Fig. 6—Wire Rib Construction Can Be Seen in This View

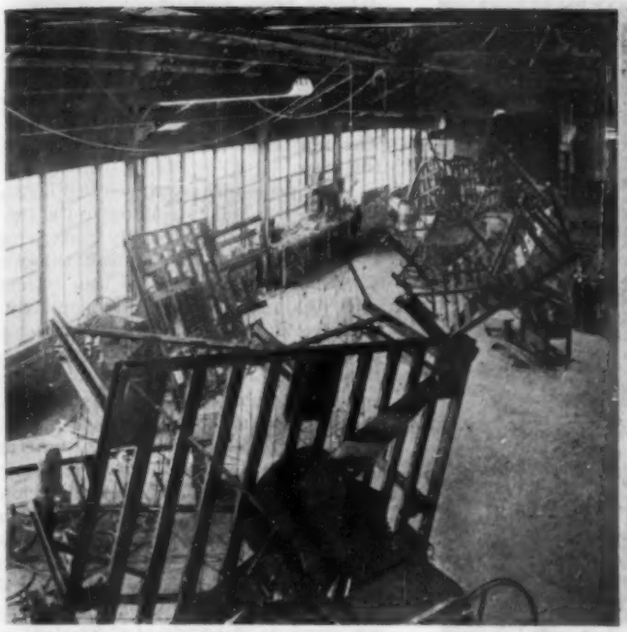

Fig. 7—Line-up of Tilting Fixtures

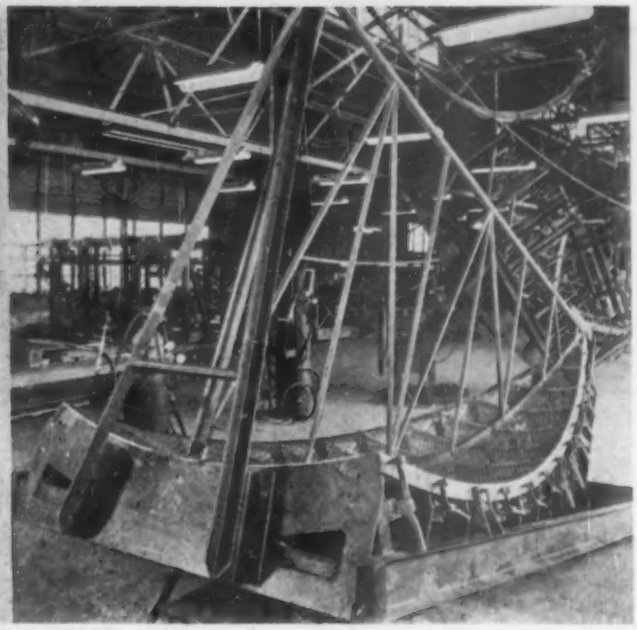

Fig. 8—An "Orange-Peel" Section of the Structure Shown in Its Assembly and Checking Fixture

is an important factor in training new operators. On brass and bronze tubes and fittings low-melting silver solder has generally been used.

In many instances especially in the fabrication of light aluminum sheets having close tolerances after assembly the use of riveting has proved more successful. The aluminum structures referred to have areas from 10 to 20 sq. ft. and have odd paraboloid shapes with tolerances of about ± 1/32 in. after assembly. In another instance with a much larger steel structure of a similar nature, spot welding was used, but had to be replaced by riveting because of the necessity of holding shape.

Except for aluminum all types of castings are generally avoided in this type of work chiefly because of the difficulty in making rapid design changes, low gun blast resistance and higher weights for equal strength in contrast to other types of fabrication.

In some cases, because of easy availability for replacement in the field, wood construction has been used. Wood has also been used where electrical interferences have caused some trouble. Low pressure molded plastics are being used more and more because of their very high resilience and lightness. These applications include protective covers of all kinds.

Although in the majority of cases arc welding has met all of the design requirements, a great deal of care has to be taken in the selection of the type of welded design to meet these requirements. As has been the experience of many designers in the past, the use of steel tubing has been found to be the most efficient from the standpoint of weight versus strength. A closed sheet metal type of structure is sometimes required however, to provide a dust-tight enclosure. One of the great advantages of using a tubular design is that proper cross section tubes can be put directly where forces within the structure are liable to occur. When using sheet metal or plate it is obviously necessary to use the material with a constant wall thickness throughout the strength members. This is a wasteful procedure because the constant wall thickness is usually not needed to provide full strength. Plate and sheet metal construction, however, sometimes satisfy the function of eye appeal in addition to the dust tightness as explained above.

The use of all types of welding on both sheet metal and tubular structures entailed the age-old problem of distortion and warpage. The sequence of welding of a tubular structure can usually control the amount of distortion in such a structure. Experience has shown that very little straightening is necessary when the proper sequence of welding has been followed. With regard to the welding of plates and sheet metal, however, the problem of warpage is very serious and many "crowbar" methods of straightening have been used for correcting such conditions. The designer is many times at fault for not specifying the allowable warpages. Obviously all structures do not have to be perfectly flat to serve their functions. The designer should realize this and should specify on the drawing the allowable warpage.

The problem of weld inspection in most welding shops is very serious and in many cases detrimental to the production rate.

Inspection of welds is a difficult job if done without the aid of X-rays, or other electrical means. Many inspectors do not have a sufficient welding knowledge and as a result they cannot visually distinguish between a good and bad weld. Pinholes or openings of any kind are not permitted in Ordnance equipment because of a possibility of salt water corrosion. Sometimes surface roughness of an otherwise sound weld has been mistaken for a porous welding, thus causing unnecessary salvage op-

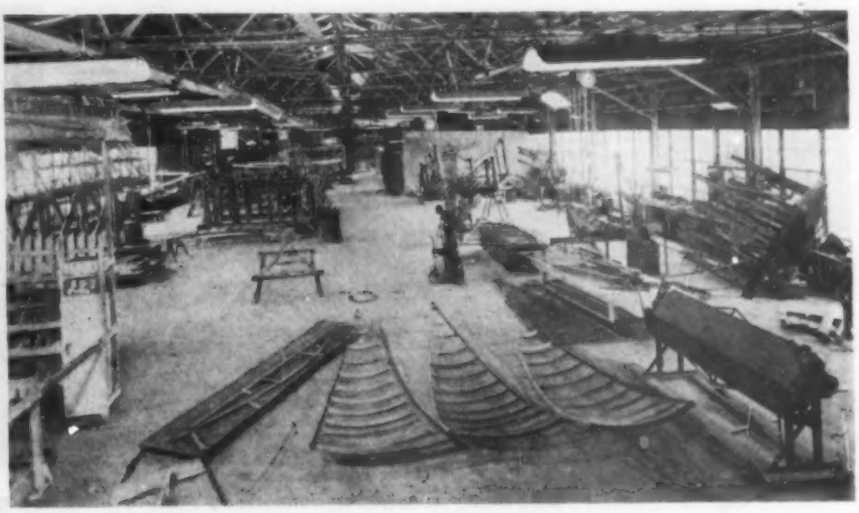

Fig. 9—Assembled "Orange-Peel" Sections in the Foreground

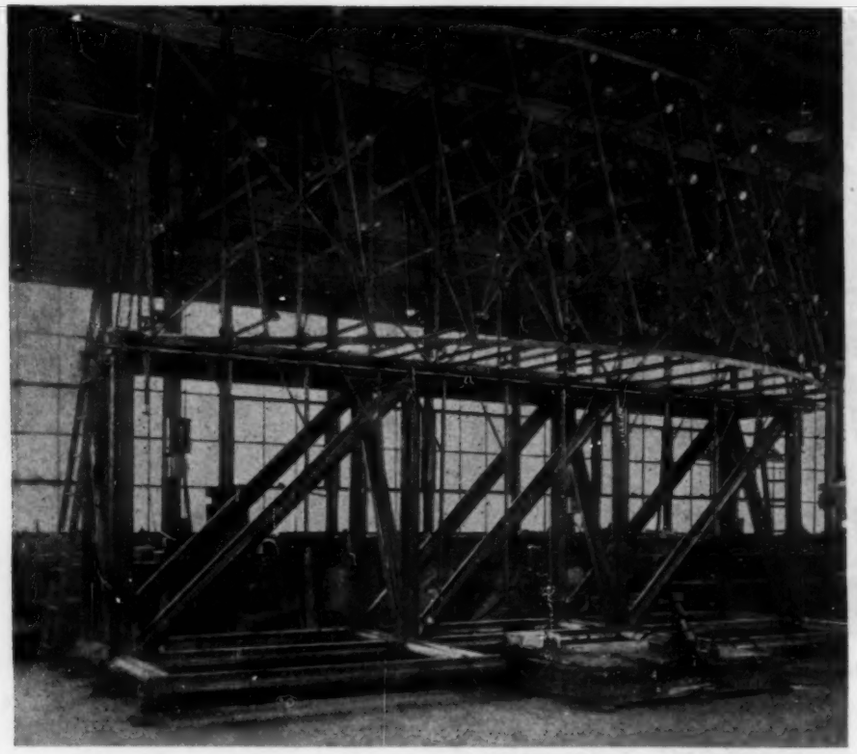

Fig. 10—Two-Story Checking Fixture for Checking the Shape of the Structure

erations, and production delays. The answer to the problem, of course, is to give the welding inspectors the same education as that given to welding foremen and operators.

We have not been concerned much with costs on Ordnance structures. We have had to work with tight time limitations on delivery and have therefore chosen whatever type of construction could be done the most quickly regardless of cost. Arc welding has generally been the answer to getting a job done quickly. As regards to cost we can only estimate what the job would have cost had we chosen another method of construction. These estimates in our designs have not been made because an entirely new design approach would have to be made in all fairness to other types of construction. Design time for making these comparisons has not been available. However, it is our belief that the most economic method of fabrication was automatically arrived at in each instance, because we were forced to choose designs which could quickly and easily be made.

The illustrations which follow, show the types of designs under discussion. It is regretted that complete assemblies may not be shown for security reasons.

Figure 1 shows a large tubular outrigger assembly, the inner portion being made of sheet steel. Two-inch diameter tubes were used for compression members and $1^1/_2$ in. diameter for tension members. The wall thickness was 0.065 in. The material was mild steel and welding in suitable fixtures did not prove too difficult for comparatively unskilled welding operators. The center sheet metal sections shown are parts of a dust-tight enclosure.

Parts of a completely welded Outrigger Jack Screw assembly is shown in Fig. 2. The tube terminations are shown clearly in this view.

Army personnel are shown in Fig. 3 assembling a tubular structure to the top of the pedestal. This assembly is made from $1^1/_4$-in. tubing, 0.065 in. wall thickness. There is no machining on this assembly after welding. It is welded completely in a fixture, and the connecting points for adjacent assemblies are welded last. All of these assemblies must be interchangeable and no machining has been found to be necessary after welding.

In order to protect machine surfaces and gearing from dust and moisture it was necessary to design a completely enclosed pedestal box of sheet steel. This is illustrated in Fig. 4. Both the stationary and rotating portions of this pedestal have been strengthened to carry the load of the structure mounted on it. The strengthening members are made of sheet steel and welded to the pedestal and turn table, respectively.

Portions of the structure mounted on the pedestal and outriggers are shown in various stages of completion in Figs. 5, 6, 7, 8 and 9. It was necessary to design this huge structure as light as possible and yet it had to be strong enough to withstand wind pressures up to 100 miles per hr. Expanded metal screening was used tack welded and wired to light truss ribbed assembly. The ribs are arc welded and made from $^3/_{16}$- and $^1/_4$-in. diameter annealed steel wire bent to shape in a fixture.

Figures 8 and 9 show a portion of the structure which was changed from a welded design to riveted design. This change was necessary to avoid excessive warpage.

The checking fixture for checking the shape of the structure is shown in Fig. 10. The base is made of heavy 6- and 8-in. tubing, while the upper portion is made from $1^1/_2$-in. tubing and structural angles. A series of probes are attached to the upper structure and protrude through the back of the checking fixture with certain plus and minus indications for tolerance. Be-

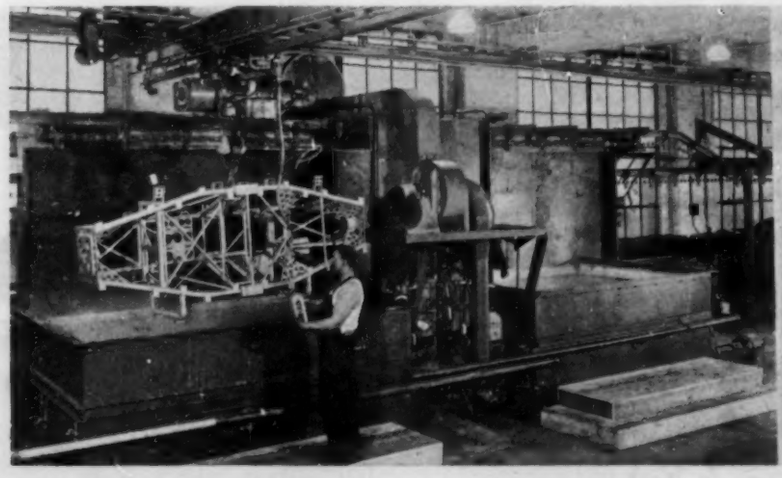

Fig. 11—Tubular Frame Being Immersed in Bonderizing Tank

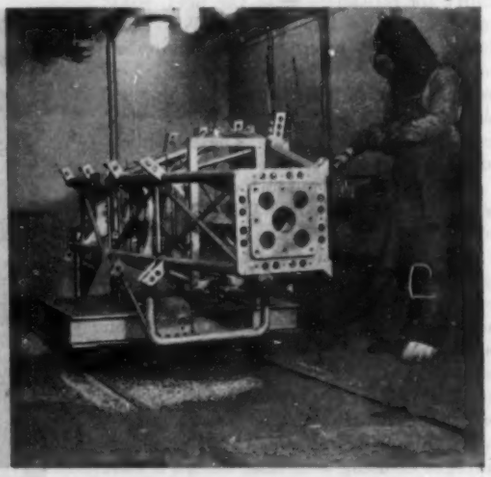

Fig. 12—Sand Blast Operations on Tubular Frame

Fig. 13—Some Subassembly Fixtures Used on Navy Project

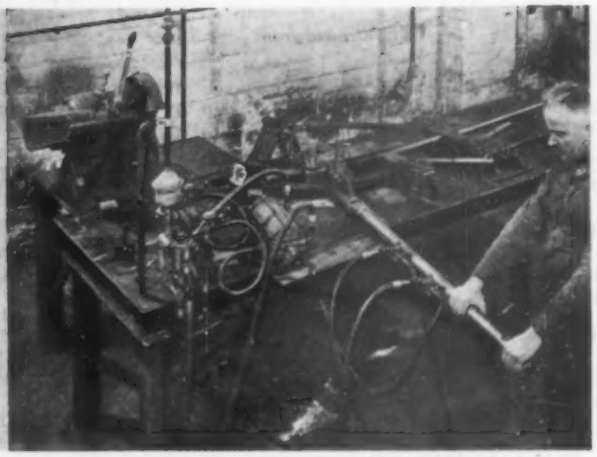

Fig. 14—Bending Machine for 2-In. Diameter Tubes

fore the checking fixture was built several days were required to check a structure. Now the time has been cut to $^1/_2$ hr. by one man.

The preceding photographs have covered a structure designed and built for the Army. The following illustrations are of some parts of a unit for the Navy.

Figure 11 is an over-all view of the supporting frame just before the bonderizing operation. This frame is entirely welded and has about 175 individual parts. There is not a great deal of machining on it and it was necessary to carefully control the welding procedure so as to avoid excessive warpage. Another view of the same frame is shown in Fig. 12 as it receives the sand-blast treatment.

The tubing used on this frame was 0.083 and 0.065 in. in thickness and the diameters were 2 and 1 in. The welding was required to be of the highest quality, and absolutely free from porosity and leaks. Only Navy qualified welders were permitted to work on the job.

Many of the subassemblies were welded in subassembly fixtures similar to the two fixtures marked *A* and *B* in Fig. 13. Fixture *C* in Fig. 13 is for welding the long tube and bracket assembly shown.

The tubes for the frame were bent to shape in a special built bending machine shown in Fig. 14. The cutoff was done in the same machine The lengths were held within $^1/_{32}$ in. and the bends were held within $^1/_{16}$ of the required bend. The tubes were bent cold without any filling and were required to be round at the bends.

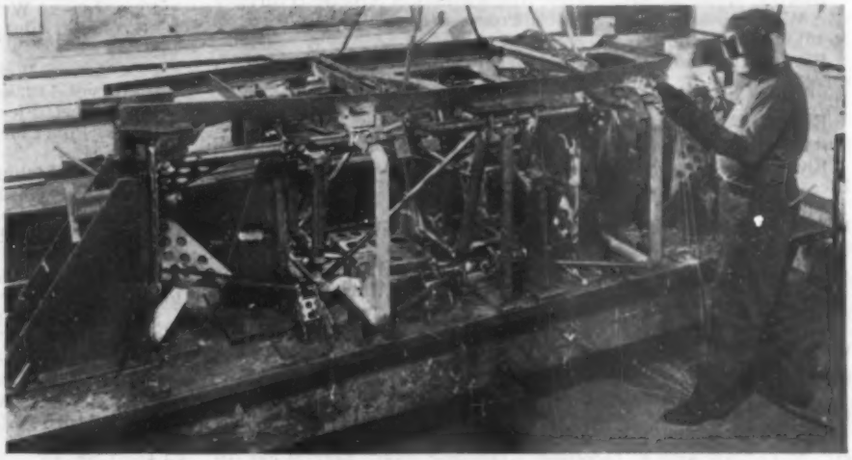

Fig. 15—Tack-Welding Fixture for Complete Frame

After the subassemblies were made and tubes bent, all of the parts were tacked together in an assembly fixture pictured in Fig. 15. The complete welding was done out of the fixture for two reasons. As can be seen, access to many of the parts would have been difficult in the fixture. Furthermore, we had only one fixture and to reach the required production it was necessary to tie this fixture up in as short a time as possible. As it turned out, we were able to control the warpage by proper welding sequence.

Acknowledgment

Ohio Aircraft Fixture Co. and Bell Telephone Laboratories.

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Resistance Welding on Stainless Steel Aircraft Engines and Accessories*

By Frank G. Harkins† and W. L. Hales†

ALL the commonly used resistance welding processes are employed in the manufacture of stainless steel airplane components. Only those which seem to be the more ingenious and interesting fabrications are illustrated in this paper in consideration of the space limitations of "convention by mail." We have adapted as well as we could our original plan of presentation, which included showing a series of slides with comments on the performance of various operations, and the display of a group of parts for inspection with discussion of some of the problems involved in the fabrications. The parts illustrated include components of manifolds, heat exchangers, cowling, jet engines and sundry others used in modern airplanes, military and commercial. Practically all of the discussion of resistance welding applications in this paper is applicable to any stainless steel fabrication requiring dependable performance under conditions of extreme temperature.

Unlike most other applications, the aircraft welds made by this company must give reliable service in a probable mean temperature of 1000° F. (see Fig. 23), with transition from 300 to 1400° F. occurring possibly in less than 10 sec. Further, the abrasive effect of carbon particles and acid formations is enhanced by the high velocity of the exhaust stream and the turbulence of the gases being confined.

Peculiar shapes are required (see Fig. 24), posing problems demanding not only considerable imagination, ingenuity and skill in metal forming, but also in development and adaptation of welding machines and tools. Until lately regarded as an accessory rather than an integral component of the aircraft engine, more often than not the manifold design must be hand-tailored around the finished engine design.

Stainless steel 18–8 of the 302, 321 and 347 varieties is the material most commonly used in the manufacture of these parts. Where extremely high operating temperatures are encountered Inconel and some of the newer high-alloy "steels" are used, including such materials as 19–9 DL, N-155 and S-245. In the spot-welding applications the range of material thickness is from 0.006 to 0.250 in. In the flash-welding applications the range is from 0.015 to 1.875 sq. in. The equipment—spot welders, seam welders, flash welders—varies in size and capacity from 15 to 250 kva. Portable welders are of the hydraulic type.

Interesting Applications

Figures 1, 2, 3 and 4 show the fabrication of an airplane part. Figure 1 shows the flash-welded, die-formed parts. After the weld is stripped in a special machine that is an adaptation of a broaching machine, the weld reinforcement is positioned by spot tacking as shown in Fig. 2. This reinforcement is then seam welded by means of a series seam-welding technique. A copper dummy bar is inserted in the part and the weld is made as shown in Fig. 3. The parts are then spot tacked into the assembly shown on Fig. 4. Here an Elkonite-tipped carbon steel electrode is used. The upper electrode is also Elkonite tipped. Carbon steel was selected for this fabrication as illustrated because the electrode cannot be thicker than 0.375 in. All the copper alloy electrodes collapsed under the 1200-lb. pressure requirement.

Figure 5 shows an unusual roll-weld application, where both seams are required to bend almost 180°. This part formerly was welded by the atomic hydrogen process. The change to resistance welding enabled us to make this fabrication in one-sixteenth the time required for hand welding.

Figure 6 is another roll-weld application that, because of poor fit, rigid tolerance and warping, had required 40 min. for assembly by hand welding. With resistance welding—spot tack in fixture and roll weld—the time is $1\frac{1}{4}$ min., a saving of approximately 97%. The arc seam

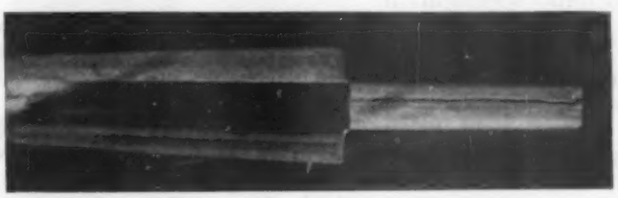


Fig. 1—Flash Weld of Die-Formed Parts to Form Finger

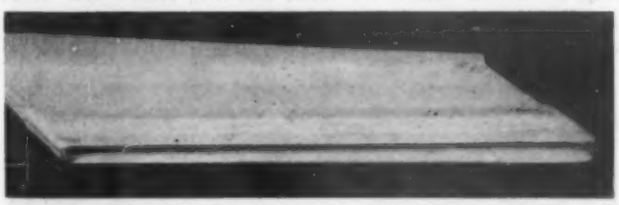


Fig. 2—Reinforcement Bands Positioned by Spot Tacking

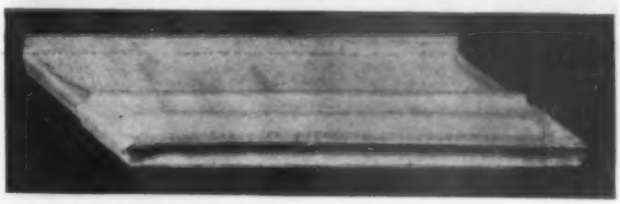


Fig. 3—Reinforcement Roll Welded by Series Seam-Welding Process

* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October 1945.
† Resistance Welding Engineer and Research Technician, respectively, Solar Aircraft Co., San Diego, Calif.

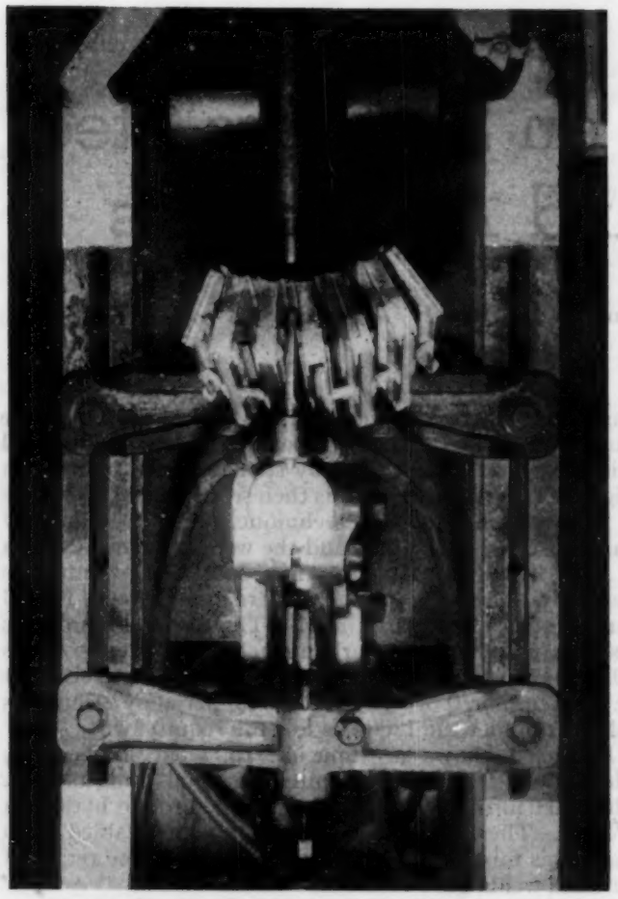


Fig. 4—Assembly Being Spot Tacked Into Position Prior to Seam Welding. Lower Electrode Is Made of Drill Rod Hardened to Rockwell C 55. Elkonite Tips Are Used Upper and Lower

shown on the side of this part is retained because of customer specification.

Figure 7 shows a flash-welded specimen of $3^1/_2$- x $^9/_{16}$-in. Type 347 stainless steel bars. The apparent indentations across the weld are the result of a Rockwell hardness traverse.

Figure 8 and 9 show the end use of this flash-welding application. The fabrication consists of forming and welding a stainless steel collar of 20 in. inside diameter, $3^1/_2$ in. wide by $^9/_{16}$ in. thick, Type 347 stainless steel, weighing 22 lb. after finish machining. Formerly made from a 138-lb. billet, by flash welding rolled bar stock and forging the part the initial investment in material is 28 lb. Thus more than 10 hr. of machining time, 110 lb. of critical material and, with stainless steel at about 40 cents a pound, about $44, are saved in the manufacture of each unit.

Fig. 5—Views of Roll-Welded Seams. Special Adaptors Were Required for This Fabrication. Parts Are Now Assembled in $^1/_{16}$ of the Time Formerly Required for Hand Welding

Figure 9 shows these rings in the various stages of processing. Those on the right illustrate the rolled ring ready for welding, the background center rings show the upset flash welds, while the background left rings show the stripped welds, the lower front center shows the rough forgings and the upper background center shows the finished rings.

Figure 10 illustrates an electrically upset sleeve made of $2^3/_8$-in. diameter by $1^3/_4$-in. long by 0.063 in., 18–8 stainless steel tubing.

Figure 11 shows a flash weld on a $12^3/_8$-in. long by 6-in. diameter by 0.050-in. thick stainless steel tube. After rounding, this tube is spun and the diameter expanded from 6 to 8 in. at the ball portion, so that the weld must show an elongation of 30%. Rejections due to splitting in the weld after oxyacetylene welding had been 25%. After flash welding, rejections are less than 1%. Production per man-hour has increased from 9 to 130 pieces.

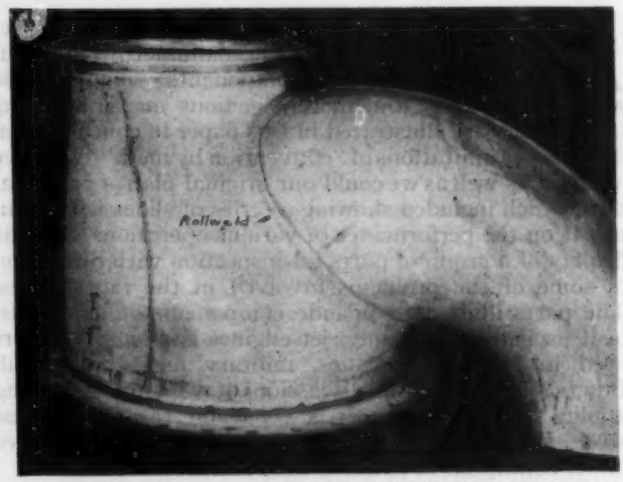


Fig. 6—Roll Weld on This Seam Saved 97% of Time Formerly Required by Hand Welding Operation

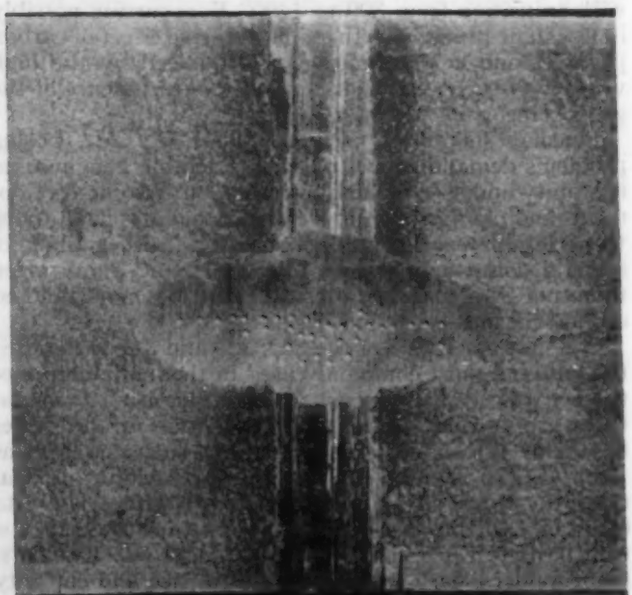


Fig. 7—Test Sample of $3^1/_2$- x $^9/_{16}$-In. Type 347 Flash Welded and Stripped. Indentations in Center Due to Hardness Traverse. Welds Always Show 100% Efficiency

Fig. 8—Close-up of Flash-Welded Ring

Fig. 10—Electrically Upset Collar Was Made from 0.063-In. Walled 18-8 Tubing

Problems

Major problems in aircraft resistance welding are (1) application and design, and (2) circumventing the established three-to-one ratio between metal thicknesses to be joined in order to procure proper weld location and penetration.

Fig. 9—20-In. Diam. x $3\frac{1}{2}$ x $\frac{9}{16}$ Rings in Various Stages of Processing. Right: Rolled Rings Ready for Welding. Rear Center: Flash-Welded Rings. Rear Left: Stripped Flash Welds. Front Center: Rough Forgings and Finished Rings (See Text)

Fig. 11—End Use of Flash-Welded 6-In. Diam. Tube $12\frac{3}{8}$ In. Long 0.050-In. Wall. Because of Spinning Operation, Weld Must Show 100% Efficiency

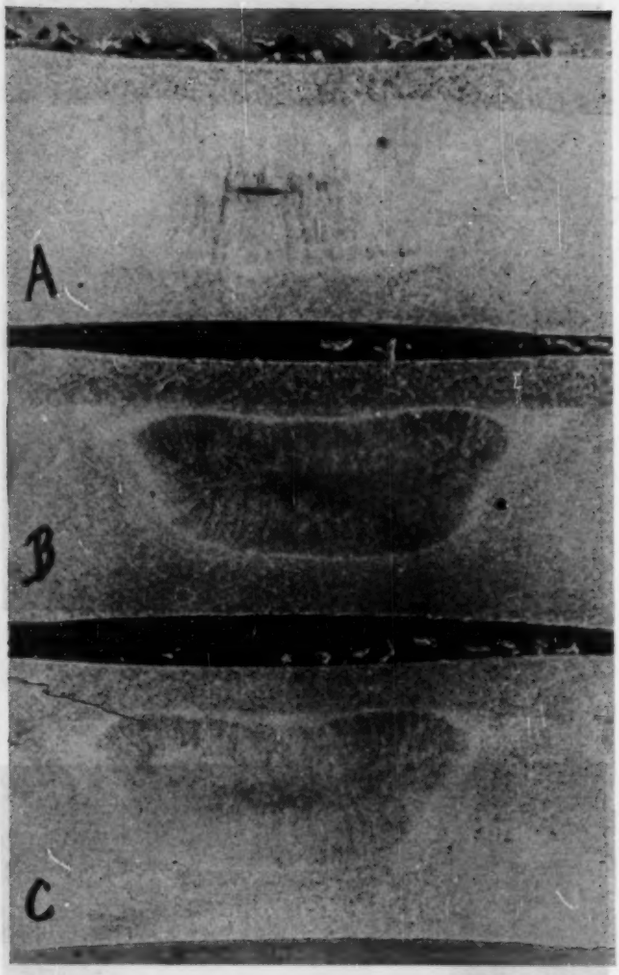


Fig. 12—No Penetration in Thin Sheets. Series Was Made with 500 Lb. Pressure; 5 Cycles; 5600 Amp. Top Electrode 8 In. Diam., 3/8 In. Face, 3 In. Radius. Class 1. Bottom Electrode Same. (Fig. 13 Shows a Peel Test of This Group)

The mechanics of reaching and holding the parts may become somewhat complicated as illustrated in Figs. 1, 3, 5 and 6. Usually the standard machine can be tooled to accommodate a given assembly provided there is a sufficient quantity of parts to be made to justify the cost of the tooling—in the aircraft industry an ever-present consideration. Use of standing flanges, which promote ease of assembly, is generally frowned upon by design engineers because of poor fatigue characteristics. Constant vigilance is required to prevent skimping the amount of lap specified by design. Once a design is established it requires almost an Act of Congress to secure a deviation: "The part is giving satisfactory service, so why change it?" Generally, customer approval is required for design changes, usually amounting

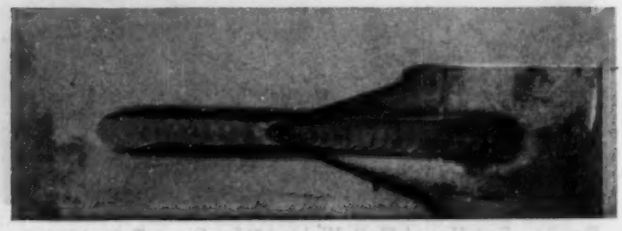


Fig. 13—Peel Test Specimen from Series Shown in Fig. 12. Almost Complete Lack of Fusion

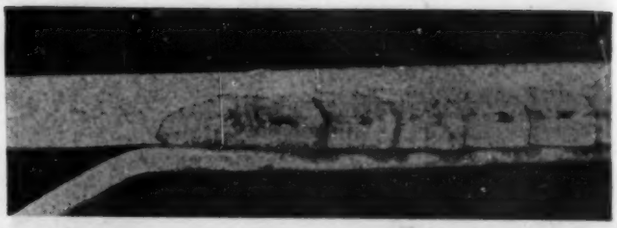


Fig. 14—Shows Effect of Increasing the Heat (Time, % Heat Dial) in Order to Demonstrate Peel Test

to service testing and months of painstaking effort. In the ordinary sequence of operations tooling must be changed and routing corrected. Cost reduction is only incidental to the major consideration of providing a better, more serviceable, part. Of course, when service life of a part is not satisfactory, design changes to provide better manufacturing practices are expedited.

Attaining the proper location of the nugget has been one of our greatest problems. In some of the jet engine applications it is necessary to weld 0.025- to 0.016- to 0.125-in. stainless steel castings. Where the requirements of the job are such that the nuggets must overlap by 50% of their diameter and the seam must show no leakage at 45 psi. hydraulic pressure, drastic measures sometimes must be taken.

To our knowledge, no classified data on the subject of "heat balance" have been published. *The Welding Handbook*, p. 329, mentions four factors: (1) thermal and electrical conductivity of work; (2) geometry of parts to be joined; (3) thermal and electrical conductivity of electrodes; (4) geometry of electrodes. Another factor directly affecting heat balance is the amount of electrode pressure. Fluctuation in air line pressure on 0.063- to 0.025-in. assembly has often caused great difficulty. No attempt is made at this time to indicate the relative importance of these factors since in any given application they are all related.

Figure 12 shows what happens when no provision is

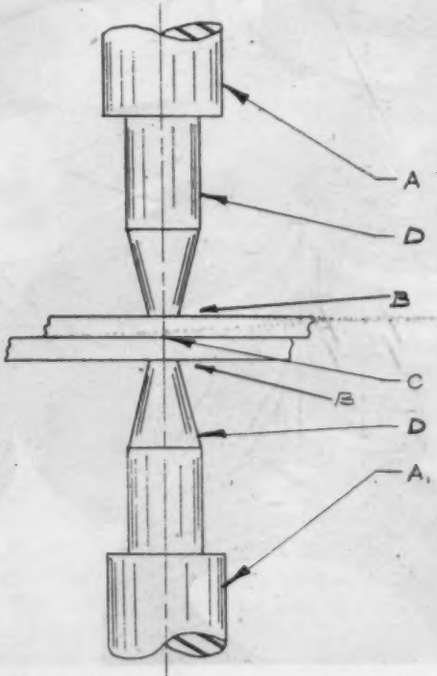


Fig. 15—Typical Spot-Welding Setup. For Explanation See Text

Fig. 16—Shows Improvement Over Fig. 12 as a Result of Decreasing the Contact Area of the Electrode. This Series Was Made with 500 Lb. Pressure, 5 Cycles, 5200 Amp. Top Electrode 8 In. Diam. 1/4 In. Face, 1 1/2 In. Radius, Class 1. Bottom Electrode 8 In. Diam. 3/8 In. Face, 3 In. Radius, Class 1. See Fig. 17

made to secure proper location and penetration. For all practical purposes a weld has been made in the heavier sheet. Figure 13 shows a peel test of this series. Where etched specimens are not examined, the ordinary procedure is to increase the heat, either by raising the percentage on the heat dial, by reducing pressure or by lengthening the time. Examination of the resulting condition, illustrated in Fig. 14, will show that penetration has been obtained but not consistently. This practice of increasing the heat encourages expulsion of metal or, at least, objectionably excessive porosity.

To solve this problem we must look into the "cause and effect" of nugget formation. The theory of spot welding is based on the formula, $H = I^2RT$, and, welding being a function of heat, the heat generated is directly related to the I, R and T factors. Change in any factor on the right side of the equation of course results in change of the amount of heat generated. Of these three, the I and T factors can be controlled adequately by the electronic panel. The R factor is subject to great variation.

Everyone who is familiar with basic electrical circuits has observed that the point of highest resistance is also the point where the most heat is generated. A loose contact always becomes the hottest point in the circuit due to its high resistance: the heat generated obeys the welding formula, I^2RT, mentioned above.

A well-known inherent characteristic of all metals is that as temperature rises electrical resistance increases.

Fig. 17—Peel Test Specimen from Series Shown in Fig. 16. Note Sharp Point at Apex Indicating Little Fusion

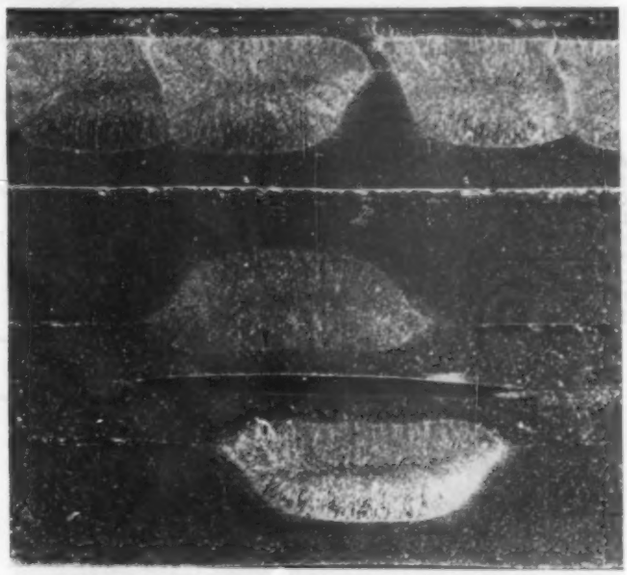
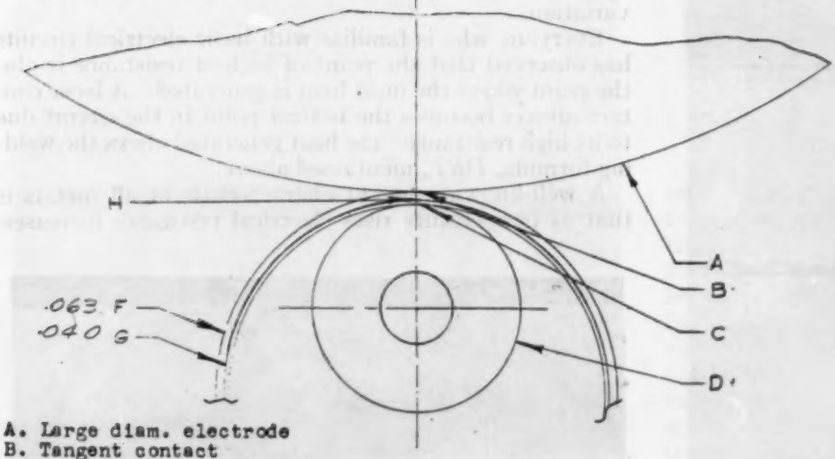


Fig. 18—Shows 50% Penetration in Thinner Sheet. Weld Shows Excellent Structure. This Series Was Made with 500 Lb. Pressure, 5 Cycles, 4700 Amp. Top Electrode 8 In. Diam. 1/4 In. Face, 1 1/2 In. Radius, Class 3. Bottom Electrode 8 In. Diam. 3/8 In. Face, 3 In. Radius, Class 1

Fig. 19—Peel Test from Series Shown in Fig. 18. Note Rounded Appearance of Apex Indicating Complete Fusion Between Parts

This is illustrated in Fig. 15: point A is the electrode holder; point D is the electrode which, during welding, remains cool because of its relatively large mass and because of the circulation of water through the inside of the holder; point B becomes warm but, due to the high heat conductivity of the copper alloy, cools quickly; point C is the point of greatest electrical resistance. Assuming that the required pressure has been established and the current turned on, heat is generated by passage of the current through the resistance of the circuit. This resistance is composed of points B, C and B. As point C has the greatest resistance, the greatest heat is generated here. As the heat at this point increases the resistance increases, causing further increase in heat,



A. Large diam. electrode
B. Tangent contact
C. Large contact area
D. Small diam. electrode
E. Nugget occurs in correct position
F. .063 Sleeve
G. .040 Port leg
H. Faying surface
I. Nugget occurs at center of work

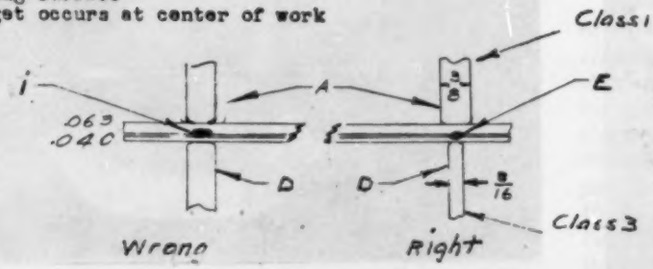


Fig. 20

and so on, until the plastic stage is reached. Continually exerted pressure causes the grains of metal of the pieces to intermingle. When the current stops and pressure remains the particles remain intermingled and a weld is made. The intermingling of the small particles from the two pieces of metal causes the indentation characteristic of spot welding.

It follows then that:

1. Parts to be welded must be clean, for if point *B* were of higher resistance than point *C* the electrode would be welded to the work.
2. Electrodes must have less electrical resistance than the work. It is an empirical formula that the conductivity of spot welding electrodes should be at least four times that of the material being welded.
3. If the pressure is too low point *C* will have excessively high resistance and too great heat will be generated causing pits, cracks and holes.
4. If the parts to be welded are not fitted properly the effective pressure is reduced, causing the same effect noted in (3) above.

When the work to be welded is of equal or nearly equal thickness, the point of greatest resistance usually is at the faying surfaces, due to oxides on these surfaces. As the greatest heat is generated at the point of greatest resistance, the major diameter of the nugget usually coincides with the line of separation between the sheets.

Quite a difference in sheet thickness can be tolerated in mild steel without affecting nugget location; however, because stainless steel of the 18–8 variety has approximately six times the resistivity of mild steel, the point of greatest resistance occurs either at the faying surface or at the geometrical center of the work. Figure 12 illustrates this condition.

If optimum nugget growth is to be attained when the thickness of one sheet is greater than two times the thickness of the other, it has been observed that corrective measures must be taken. Obviously the heat can be made to occur at the faying surfaces only if they can be made to be the point of greatest electrical resistance. Variation of the *R* factor is not considered practical at this time because of the problems involved in treating the surfaces of the metal to obtain uniformly high resistance. (NOTE: For example, plating is undesirable as it raises the cost beyond that which can be justified by the advantage gained.) Practical variations of the *T* factor to obtain the desired result have not become apparent, leaving the *I* factor to be considered.

Referring to the welding formula, it is seen that the heat generated is the function of the amperes used. If a portion of the thickness to be welded can be made to pass more current through a smaller area than other parts of the same piece, the greatest heat will be generated where the path is the smallest. Greater heat can be generated at the faying surfaces if the current density at this point can be sufficiently increased.

Fig. 21—Etched Specimen of 0.093- to 0.050-In. Assembly. Saw-Toothed Effect Is Caused by Low Top Electrode Contact Resulting in Severe Surface Burning

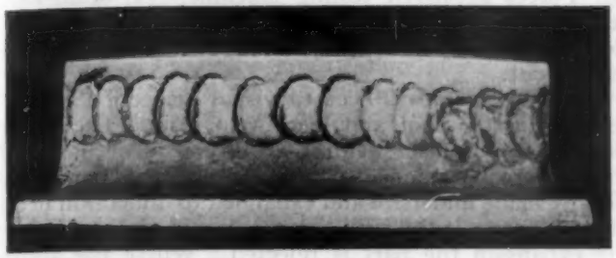


Fig. 22—Side View of Fig. 21 Showing Excessive Surface Disturbance as a Result of the High Heat Caused by Low Contact Area of Upper Electrode

In stainless steel aircraft welding it is common practice to use a small electrode against a thin sheet and a large electrode against a thick sheet. This in itself rarely causes a sufficient increase in current density, as indicated in Fig. 16. Figure 17 shows a peel test of this weld and discernible improvement over Fig. 12. A further gain is made by using a small electrode of Elkonite or beryllium copper against the thin sheet and a Class 1 electrode against the thick sheet. This gives the result shown in Fig. 18 and Fig. 19 shows a peel test of this specimen. (NOTE: Any copper alloy not containing aluminum or zinc could be used in place of Elkonite. Elkonite is used because of its greater compressive strength and resistance to wear.) The basic idea is to achieve greater heat in the thin sheet by means of higher "contact drop."

Many of our applications require spot or seam welding the electrically upset sleeve shown in Fig. 10, which enables all portlegs to be brought into the same plane (±0.005 in.) and also supports the manifold on the engine. Assembling this sleeve, which usually is a much heavier gage than the manifold, poses a serious problem of heat input similar to that illustrated in Fig. 20. The top electrode can make only point contact due to the geometry of the parts. The lower electrode, due to the small diameter, contacts about 1½ in. of the tube. The result is that surface burning occurs as shown in Figs. 21 and 22, illustrating unacceptable work. Figure 22 is taken 90° from Fig. 21. When the sleeve is positioned over the assembly, no problems are involved in spot welding by means of the lapped spot technique, using an Elkonite-tipped electrode for the lower and a Class 1 electrode for the upper. This is a poor application for roll welding as the metal pile-up is the reverse of what is usually regarded as good practice; however, roll welding is seven times faster than lapped spot welding and should be used if at all possible.

Fig. 23—Illustrates the Type of Service to Which Solar Manifolds Are Exposed. Photo Was Taken at Night in a Solar Test Cell with No Lighting Other Than That Radiated by the Manifold. Temperature Is Approximately 1400° F. Manifold is Attached to R2600-8 Wright Radial Engine. Due to Opening of Exhaust Valves Manifold Must "Breathe" (Pulsate) 18,200 Times per Minute at Top Rpm. Quality of Welding Required to Be Dependable Under These Conditions Will Be Apparent

Fig. 24—Typical Exhaust Manifold Ring of 0.050-In. Stainless Steel. Port Legs Are Held to 0.005 in Relation to Each Other. This Is Remarkable Tolerance for Sheet Metal Parts

Increasing the contact area of the top wheel, by using a larger diameter and a wider wheel, will give limited aid, but large diameter wheels are expensive and machine design restricts their use. The solution (see Fig. 20) has been to use a ⅜-in. face Class 1 wheel against the outside and a 1¾-in. diameter Class 3 wheel with 1½-in. dome radius as the inside electrode. Electrode pressure has been reduced from 1200 to 900 lb., to prevent identation and to reduce maintenance of the lower electrode.

The number of variable factors has prevented any established criteria for determining exact electrode size

for each application. We feel that flat test strips are not acceptable test specimens when the work being welded is of small diameter, and that the foregoing macrographs definitely establish that, in order to procure specimens representative of a specific job, the contour of the specimen must simulate the contour of the production part.

Inspection, Testing and Control Problems

All resistance welding on aircraft parts must conform to Army Air Forces Specification 20011. In most cases Solar Aircraft Co. standards exceed those of this specification.

Spot and seam welds are given tension-shear tests at each job change or, in any case, at intervals of not more than 40 min. Quick etch specimens are made at the time of testing. Test specimens must simulate the part being welded. They must be of the same gage, in the same order, of the approximate shape and of the same type of steel as the part they represent. Tests include: (1) visual examination for weld dimensions, indentation, surface porosity, pits, cracks and splashes, uniformity; (2) metallurgical examination for internal porosity and penetration, using an etchant of 10% oxalic acid electrolytically; (3) mechanical testing performed in an Army Air Forces approved testing machine; (4) seam-weld testing includes "peel" testing, section and etch. Nondestructive (X-ray or gamma ray) inspection is not carried out.

Flash welds are subject to visual inspection for defects as in the spot and seam-weld tests. The major portion of our flash welding is on collars or bands of various cross section and diameter. These bands are usually made undersize and expanded to dimension in an air expander. If the weld shows any sign of distress during expansion the part is rejected. Where the above elongation test is not applicable, the first five parts of any run are tested to destruction. The welds must show at least 90% efficiency. Then 50 parts are run and the 51st part is tested to destruction. The standard bend test for arc or gas welding is also applicable to flash welds. X-ray or gamma ray testing has not been adopted. Test reports are kept available for inspection by the Army Air Forces representative.

The result of this control program has been that the number of reported field failures traceable to defective resistance welding has been infinitesimal. It is perhaps understandable that we take great pride in having achieved the Army Air Forces Approved Inspection Rating.

Discussions on "Maintenance and Repair of Oil Pipe Lines"*

By A. N. Kugler†

MR. WILDMAN'S paper is both timely and interesting in that it provides information on the performance of welded and other pipe lines and means for continuing these lines in service when they have been damaged. It is to be regretted that Mr. Wildman has not provided illustrations (either photographs or sketches) of some of the more important techniques. Further, additional details on several procedures would be helpful.

To those who were connected with welded pipe lines in the early days, it is gratifying to note that the principal source of failures is not the welded joints but rather corrosion—both external and internal.

The method described for replacing defective valves, while not new, does point to the need for welding end valves for this and other classes of service. Such valves are available for high-pressure, high-temperature service but these types are too heavy and costly for pipe-line installation.

The statement that all oil companies require the casing of oil pipe lines through a camp site would be clarified by definitizing the type of camps. Under present conditions it is presumed to mean military encampments but conceivably might be interpreted as construction or even summer camps.

The method for the repair of leaks is difficult to follow since no detailed description of the "clamps" is provided. Illustrations at this point would assist materially, particularly since it appears that several different types of clamps are needed.

In the discussion of the use of scrapers, reference is made to the installation of a by-pass around a scraper stuck in the pipe. It would be helpful to know the size of the by-pass relative to the main line size. Obviously a full size by-pass is impractical. However, a small one would be of little value. Therefore, it seems important to indicate how to determine the size of the by-pass.

The details on welding techniques could be amplified, particularly for the benefit of those who may not be familiar with this type of work. For example, while E6010 electrodes may be used for "practically all welding," it would be distinctly helpful to know the specific instances where other electrodes are employed together with the reasons. Similarly, the sizes of electrodes, the number of passes and other data would be valuable.

Maintenance work in general, and on pipe lines in particular, calls for a high degree of skill and ingenuity. Work is generally of an emergency nature and must be performed under hazardous conditions. Therefore, the fact that the author has devoted parts of his paper to the discussion of these safety problems indicates that he is well versed in his subject. Mr. Wildman is to be congratulated for his contribution to our data on pipe-line maintenance.

* * *

By H. C. Price†

FIRST, let me congratulate Mr. Wildman on having written a very clear cut article from a practical point of view. He has described the method of repairing a pitted pipe line while the line is in use. However, he has cited only one method of repair, i.e., where the pipe line is kept intact in the ground. There is another method extensively used, which results in a more thorough repair job. With this method, the first portion of the pitted line is replaced in an adjacent ditch by the new coated line. The new line is then tied into the old line, and the portion which has been disconnected is taken out of the ground, reconditioned and recoated for

* Paper by Oliver Wildman published in the November issue of THE WELDING JOURNAL.

† Mechanical Engineer, Applied Engineering Dept., Air Reduction Sales Co.

† H. C. Price Co., Bartlesville, Oklahoma.

corrosion protection. The reconditioned pipe is then relaid adjacent to the old line, and also tied in. This process is repeated until the entire line is reconditioned and relaid. The only interruption of service is the time required to cut the new line into the old one. The only additional pipe needed is that for the first section. As the pipe is taken up, it can be cleaned, straightened, beveled, pits welded, and recoated at a central plant. We have found this method more efficient and less hazardous than repairing the line in place. We have also found that by using a shotblast machine at the central plant we obtain much better cleaning, particularly in the pits, than by any other cleaning method.

Mr. Wildman correctly calls our attention to the difficulties encountered in repairing pitted pipe lines. Many of these lines were laid years ago before modern anti-corrosion methods were used. I think we all realize that by using the most advanced protective methods there will be less corrosion and less repairs in the future. I wish to quote from an article by E. J. Mary and W. C. Berger published in *The Oil and Gas Journal* of September 22, 1945, which describes the construction in 1941, and operation of a 230-mile line between McPherson, Kansas and Council Bluffs, Iowa.

"Pipe chosen for the service was 6-in. nominal i.d. and $6^{5}/_{8}$-in. o.d. seamless pipe fabricated in random lengths averaging 43 ft. and weighing 17.2 lb. per lineal foot. All pipe sections were mechanically cleaned and coated with special bituminous primer and then covered to a thickness of $^{7}/_{16}$-in with Somastic coating using asphalt as a base and combining graded sand, asbestos fiber and limestone dust."

"Provisions were made for determining induced current in the line by installing electrodes each of which consisted of a brass rod welded to the pipe at intervals of 3 to 5 miles. These rods were protected by encasing them in 2-in. pipe insulated from the pipe line by Somastic; the annular space between the brass rod and the 2-in. pipe was filled with hot asphalt. By means of these brass electrodes it is possible to get a positive check on the condition of the Somastic coating covering the entire line."

"Installation of the brass rods was made in anticipation of a later need for cathodic protection, furnished $1^{1}/_{2}$ years after the line was put in operation. For cathodic protection, ground beds and copper oxide rectifiers were installed at two points along the line for supplying a small amount of current (4 amp. at 4 v. direct durrent) which has been sufficient, to balance the electrical charges over the length of the entire pipe line and protect it from electrolytic corrosion. No leaks of any kind have developed nor has there been any measurable loss of products from any cause such as pipe taps or line breakage."

* * *

By P. M. Mattern†

THE author, in his paper dealing with maintenance and repair of oil pipe lines, has presented information of a different nature than that usually encountered in technical papers or publicity dealing with the general subject of transportation pipe lines. The general public usually hears only about the spectacular features, such as newspaper publicity in connection with the Big Inch and Little Inch lines that were constructed during the war. Those who have access to technical publications usually find the type of paper which deals only with the factors involved in the initial construction of pipe lines.

Relatively few give any thought to the many problems of maintenance and repair that exist once such pipe lines are placed in operation. After reading this interesting and instructive paper, one can readily understand how varied the types of repairs must be. It appears that the welding involved is handled in much the same manner as the majority of repair welding in other industries; that is, the selection of welding procedures is left largely in the hands of the foremen and welding operators rather than being placed under the control of a single individual in an attempt to develop standardized methods. The latter method of handling repair activity usually proves advantageous only where numerous items are involved and the same repair must be made on large numbers of each of those items.

It appears, on the basis of what has been said in this paper, that each repair job is sufficiently different that standardized procedures would not be applicable. On the other hand, there is indication that there is some general standardization on repair methods. One would also assume that there is probably also some standardization of welding procedure, although it is not indicated in this article other than the use of a single classification of electrode.

Fortunately, the material of which the pipe is made in practically all cases is mild steel and therefore quite readily weldable. Because of this, detailed and well controlled welding procedures are no doubt unnecessary. This being the case, one can readily understand why the entire matter of welding procedure can be left with safety in the hands of the foremen and welding operators with little or no concern as to subsequent difficulties.

† General Sales Manager, Wilson Welder & Metals Co., Inc.

Discussions on "Power for Welding"

By C. M. Rhoads, Jr.†

THIS paper outlines very clearly the problems associated with the provision of power for resistance welding machines.

Regarding the question of the use of three-phase versus single-phase connection of step-down transformers, it is true that the transformer connection does not change appreciably the effect of single-phase welder load in producing voltage drop ahead of the transformers; therefore, the decision as to the best connection to use will depend upon consideration of the number, location killovolt-ampere demand of the welders and allowable percentage of rejects. It should be noted that when we say that the voltage drop due to the impedance of a single-phase bank of three transformers in parallel is one-half that of a three-phase bank for the same welder load, we assume the same kilovolt-ampere rating and impedance of each bank.

If the welders are located so that one group is fed from a single-phase bank and the other groups are fed from separate banks connected to other phases of the distribution lines, only one-third of the total kilovolt-ampere

* Paper by L. W. Clark published in the September 1945 issue of THE WELDING JOURNAL.

† Industrial Engineering Division, General Electric Co., Schenectady, N. Y.

rating of all transformers will be used to feed one group of welders. On the other hand, if all transformers are connected three phase, the drop on the loaded single-phase line is not as great as it is when one-third the bank is used. A simple example will show this. If we take 1500 kva. of transformer capacity composed of three 500-kva., single-phase, 5% impedance transformers, the drop due to a 500-kva. single-phase load on one transformer will be 5%. If we connect the transformers 3 phase, the drop due to a 500-kva., single-phase load will be two-thirds of 5% or 3.3%. When the groups of welders on all phases hit together for 1500 kva. demand the voltage drop will be 5% on all phases.

The frequency of simultaneous welds is also important since this will determine the percentage of welds made at less than the required welding current. With the single-phase connection and one-third the welders on one phase, the voltage drop will be maximum when all of those welders hit together. The welders on the other phases will not have any effect due to transformer impedance but may have some slight effect due to common high-voltage line impedance.

If the three-phase transformer connection is used, the maximum voltage drop will occur when all welders on the three phases hit together. It is evident that all welders will hit together on one phase more often than the welders on all phases will hit together; therefore, for the same kilovolt-amperes of transformers maximum voltage drop will occur more frequently with the single-phase connection.

As Mr. Clark has pointed out long low-voltage bus runs should be avoided wherever possible. Location of the transformers and associated low-voltage switchgear within the plant at points of greater load concentration is very easily affected with load-center unit substations. These substations consisting of dry type or noninflammable liquid-filled transformers and integrally connected air-circuit breakers have been widely used in industry for operation from 15 kv. and lower voltage lines. Such unit substations are easily installed and easily moved if welders are rearranged, thus permitting short low-voltage runs with a saving in the cost of bus-work and with improvement in voltage drop.

The selection of low-voltage circuit protective equipment of adequate interrupting capacity is essential to the safety and continuity of operation of a resistance welding power distribution system. When systems are designed for low-voltage drop, the available short-circuit current is increased and care should be taken to insure that the system design is not such as to call for short-circuit currents which are above the ability of standard protective equipment to interrupt. Power fuses have very definite limitations as to the current which they can interrupt; beyond this value fuses may fail to clear and may be destroyed with possible damage to other equipment before back-up protective equipment functions.

Air-circuit breakers of 100,000 amp. interrupting capacity and below are generally available and where correctly applied give positive protection with very little maintenance required. Since the cost and size of air-circuit breakers increase rapidly as the interrupting capacity increases, it is desirable from the economic point of view to consider the possibility of sectionalizing the transformer banks and the welders so as to permit the use of breakers of moderate interrupting capacity. The use of "cascading" or using a back-up breaker for several smaller breakers, can also be used if the possible shut-down of a group of welders for a short time can be tolerated.

Mr. Clark has pointed out the benefits of the use of low-voltage cables and bus bars having low reactance obtained by close spacing of the conductors. The users of resistance welding equipment will no doubt be gratified to know that bus and cable with low reactance are readily available and special designs are no longer necessary by each user of welders. Concentric cable giving very low reactance is available in braid, lead and interlocked armor design. Such cable is easy to install since the two conductors are incorporated in a single circular cable.

Separate single-phase feeders to the larger welders are often economically feasible and have the advantage of eliminating interference voltage drop on a bus feeding several welders.

Enclosed bus duct with close spacing of the bus bars to give low-voltage drop is available from the manufacturers of standard forms of enclosed bus. This enclosed bus is constructed to have safe insulation levels and is adequately braced so as to withstand the high short-circuit currents which can be developed on a welder bus.

The question of the selection of low voltage is intimately tied in with the selection of low-voltage cable and bus. Four-hundred eighty-volt systems are to be preferred for nearly all resistance welding applications. With 480 v. the current per kilovolt-ampere of welder load is one-half that at 240 v., while if the same cable or bus is used, the voltage drop in per cent of the line voltage will be only one-fourth of that at 240 v. for equal kilovolt-ampere loads. Thus 480 v. makes possible a large reduction in the secondary circuit voltage drop and also permits the use of smaller less expensive conductors.

* * *

By Foster R. Woodward†

Mr. Clark's "Power for Welding" in the September issue is an excellent discussion of general power supply problems.

The progress in the development of low-demand resistance welding equipment systems has been necessitated by the fact that the average welder user is served by power distribution systems less accustomed to handling resistance welding loads than is the Detroit Edison Co.

Low demand resistance welding equipment developments may be classified as: (1) stored energy systems, (2) power factor correction systems and (3) special machine designs.

Stored energy usually will have lowest electrical demand because the energy required for the production of a weld is taken from the supply system over a longer period of time than the time during which this energy is discharged through the weld. Low demand is thus associated with a long time available for energy storage.

Electrochemical stored energy or "battery welding" systems have very low supply demand, because the batteries may be charged continually with the actual "weld time" being 10% or less of each sequence cycle time.

Electrostatic stored energy systems enable energy storage during that time when the weld discharge is not taking place. Electromagnetic systems usually take power from the line during that period when the electrodes are together, before the weld discharge occurs.

Power factor correction equipments will include series capacitors, shunt capacitors and electronic, three-phase–single-phase conversion units and decrease line demand by improving the power factor of the load.

Power demand may also be decreased by the machine

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design. For instance, many multispot assembly problems lend themselves to solution by means of series welding, whereby the same welding current is carried through several welds arranged in series; thus, several welds are produced with the same current required for one weld. Power factor is usually somewhat improved by this method.

On specially designed machines for a particular welding job, use of multiple transformers with short secondary conductors and lower secondary voltage requirements will result in decreased demand load. Low impedance welder transformer design is practiced by most manufacturers, together with low resistance secondary circuits.

Increased original costs for stored energy and power factor correction equipments, together with higher maintenance costs, have interfered with universal application of these setups.

Single-phase, normal power factor welding equipments will continue to be most commonly used in the foreseeable future. We anticipate that series capacitors will find more usage on seam welding equipments where the duty cycle is relatively high. We also find that for low duty cycle jobs, the electrochemical stored energy offers definite advantages in simplicity in design and low maintenance requirements over other stored energy methods.

In practice, however, each installation must be analyzed individually and the factors of power supply characteristics, power demand, permissible voltage drop, weld consistency requirements, anticipated future load additions, quality of maintenance available, etc., must be considered to arrive at the solution to the economic problem of the correct equipment for the required production job.

* * *

By R. E. Young†

Too few of today's engineers are gifted with the ability to describe their knowledge and data before an audience in a concise manner with simple everyday language interesting to all present. In my opinion, L. W. Clark's address "Power for Welding" recently given before the Detroit Section of the AMERICAN WELDING SOCIETY, marked him as one of these few engineers. Like some experts in other professions, an engineer often spends a lifetime working on a special field of his profession but when he stands before an assembly of other engineers, or before the general public, he is unable to concisely present an over-all picture of his subject.

Mr. Clark and others have adequately covered in other addresses why welders are a desirable load due to the almost always accompanying increase in lighting and other power loads which result in an increase in revenue substantiating the original welder service expenditure. However, there are instances when the return from the welder service investment does not warrant such an expense without the customer sharing some of the cost. This subject, undoubtedly, could be a topic for a separate address before the SOCIETY, but I do feel that the speaker might have touched on it in order to completely cover his subject, "Power for Welding."

In general, each utility company handles these unusual cases with varied types of special charges. These varying methods have been criticized by some who feel they are "imposed" on the welder user. From studies made by the Public Service Co. of Northern Illinois it has been found that most of the adopted policies of those utilities, who are serving these unusual welder cases, can be classified into four methods as follows:

1. The utility asks the welder user to pay for certain of those utility investment costs which are additional to those required for normal power and lighting load. Sometimes maintenance charges and equipment rentals are requested.
2. Special minimum charges, other than those provided in the regular rate schedule, are sometimes requested. These minimums may be based on the measured instantaneous demand, the required transformer capacity, a percentage of the total utility investment or nameplate data.
3. The demand charge of some utility's standard rates are sometimes increased by basing the demand in lieu of an integrated demand (for instance, a 30-min. period) upon a measured instantaneous demand, on a shorter time interval than that of the regular metering, or on a percentage of the instantaneous load.
4. Some use a combination of the above three.

From careful study it has been found, however, that in all policies investigated, the utility involved was concerned only that its unusual investment be protected, rather than requiring its other power customers to stand investment for service to an individual welder consumer.

† Power Engineer, Public Service Co. of Northern Illinois, Kankakee, Ill.

Discussions on "Some Fundamentals in All-Welded Ship Construction"*

By Edward M. MacCutcheon, Jr.†

I BELIEVE the article entitled "Some Fundamentals in All-Welded Ship Construction" is the beginning of a revolution in thought regarding ship construction by welding. It points up the general trend away from concern about residual stresses and it is encouraging to see that the ship constructors are taking such an interest in the research and investigational work which has been carried out in the past two years. It is only through the sympathetic interest of these people that the findings from these studies can be given wide practical application.

I agree wholeheartedly with Mr. Forman's contention that an all-welded ship is a practical and feasible possibility and furthermore that we are now in a position to build such ships without the aid of riveting. All-welded ships, however, should incorporate many features which are not now being generally employed in ship construction. One of the most important of these is a change in the required characteristics of the steel used for the hull construction. Unless there is some assurance that the steel for the hull is tough and not susceptible to notches in the normal operating temperature range, we can have no assurance that an all-welded ship will be a desirable risk.

One hundred per cent perfection in workmanship in the yard cannot be expected or attained, but what is more important, later alterations, additions and local damages which occur to the ship in service, etc., produce numerous notches in the structure which might serve as the

* Paper published in the October 1945 issue of THE WELDING JOURNAL.
† Lieutenant Commander, USCGR.

source of fractures. In addition to tough steel, however, every care should be taken to make sure that the ship is entirely free from various types of notches when it is built. As Mr. Forman points out, great care is required in the design details and later in the workmanship of construction. The use of radiography for the hull has proved to be both reasonable and practicable. Some yards are already using this method of internal inspection of welds. A radiographic survey of the critical portions of the hull can be done with 500 to 600 exposures. Care must be taken to proportion the number of pictures in accordance with the importance of the joints and to make full use of psychological effect produced by a random selection of locations of which the production department has no previous information.

There are several points in this article to which I would like to make specific reference. I believe that a bulwark free from the sheer strake and supported only by the braces is superior to the bulwark with intermittent slots as indicated in Fig. 4, because fractures have frequently occurred at the end of similar slots in existing vessels. In the list of locations which are said to be the starting points of serious fractures, I note that No. 3 is indicated as faulty weld at the gunwale connection. I know of several cases where fractures have started from welds attaching members to the top of the sheer strake but I do not know of a single failure where the fracture was positively traced back to the weld between the deck and the sheer strake. The gunwale weld is mentioned again later on with regard to the details of design. I agree that the doubler fillet weld is an easier weld to make but in many cases it has been found that where insufficient care has been taken in fitting parts, this weld is cracked in the root. These cracks are longitudinal and in one vessel were found to extend almost completely around the deck. It is remarkable that no further damage occurred.

It is my opinion that Mr. Forman deserves a great deal of credit for his foresighted approach to this problem.

* * *

By John Vasta*

The author of this paper has ably reviewed what appear to be some of the most important fundamentals related to the welded ship. By emphasizing the remedies taken, however, he gives the impression that the problems associated with the welded hull have been permanently solved. It is encouraging, therefore, to note in the conclusion the statement "that there are still many problems to be solved and there is much research to be done." To this philosophy one would heartily agree.

During this past national emergency, which saw mass production methods applied to ship construction, welding played a predominant part. It took the spectacular breaking-in-two of the S.S. "Schenectady" to awaken us to the fact that something very serious could be the matter with welding. This unusual ship behavior served as an impetus for many agencies associated with shipbuilding to study and investigate the many problems related to the welded hull. Some of the practical remedial measures which the author discusses in his text gradually ensued as a result. These, however, need be considered as temporary in character, to be further perfected as the results of research become known and are applied.

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The structural design of a hull is influenced by the method of fabrication and assembly if welding is contemplated. Such factors as rigidity, residual stress, stress concentrations and notches play an important part here. Welding, in joining the component structural elements of a hull into one continuous unit, gives us a very rigid structure. If poor design details improperly executed in the field with inferior welding are present, however, the primary strength of the hull may be seriously impaired once a crack initiates at a notch. It is this dangerous exhibition that makes an all-welded ship a challenging research problem. In spite of the wealth of experimental data accumulated to date, the explanation of why one vessel breaks in two and a sister ship, built by the same yard presumably under the same condition, does not, is far from being complete.

The difficulties encountered in understanding this perplexing behavior are many. Attention may be invited, for example, to one of the many factors which is so loosely spoken of as being chiefly responsible for major structural casualties. This factor is stress concentration. All of our basic concepts about stress concentration have been associated with definitions of stress and say little about the actual deformations or strains. We usually speak of a test piece rupturing when it has sustained a certain average stress. In the sample test coupon this stress has been defined as the ratio of the applied load to the original cross-sectional area of the specimen. When we shift emphasis from the simple laboratory specimen to a complicated structure, such as the hull, the term "stress" no longer has the initial definition associated with the test coupon. In making measurements, all we can observe is an elongation or contraction. This we manipulate mathematically in order to define stress. Within limits of the yield strain, the calculations for stress are rather simple. When the yield strain is exceeded, however, the calculations for the corresponding stress become more complicated and the term is less understood. To illustrate this point, let us consider a flat plate, under tension, having a circular hole at the center of the plate. Theory tells us that a stress concentration factor of 3 occurs at the edge of the hole. Yet, as soon as the average stress across the net area is raised until the yield strains at the edge of the hole is exceeded, the stress concentration factor is no longer 3, and at once ceases to have the original significance and diminishes with increasing applied loads.

Thus far we have hinted at the behavior of elastic materials capable of suffering large plastic strains—a prerequisite to reduce the stress concentration peak. The ability of any steel specimen to flow under increasingly higher loads is a desirable attribute. This develops the maximum tensile strength of the material and is usually characterized with a shear or ductile fracture. The action of the same material prevented from flowing freely by the effect of a sharp notch is much different. The notched specimen not only fails to exhibit the strength and ductility that are obtained from the conventional 0.505-in. round tensile test specimen, but fractures in a brittle or cleavage manner. The mechanism of rupture influenced by a sharp notch and strain hardening effects presents concepts which plague the mind of the hull designer.

In joining the structural elements together welding tends to define more markedly the geometrical discontinuity. This accentuates the severity of any such notch. For example, in an all-welded ship the square hatch corner is a definable geometrical discontinuity. In a riveted hull, the same square hatch corner detail would differ in two respects: first it would be more flexible than the welded detail because of the relative limberness of the riveted construction, and secondly,

the "sharpness" of the corner would not necessarily coincide with the geometrical outline. In the latter case the rivet line controls the boundary. This singular property of the welding process has a marked effect on design. It emphasizes that the changeover from riveting to welding must be accompanied with a clear understanding of these important factors if the structure is to be free from any structural deficiency.

Much has been said about steels possessing low notch impact resistance or having high notch sensitivity. Welding, in a way, has been responsible for bringing to proper light this question of materials, not because the basic properties of ship steel were undermined by welding but because welding as a by-product was responsible for accentuating the sharpness of the notch. Considerable experimental work has been done, and more is in progress, on the mechanism of the cleavage fracture of steel under various conditions of temperature and multiaxial state of stress. There is no doubt that valuable information will result from this and other related research activities. In the meantime, while the designer is awaiting these results, the remedial steps enumerated in this paper constitutes the best practical compromise to some of the more glaring deficiencies. Certainly every effort should be made to improve the quality of welding. As an added measure of safety it may be desirable that the visual inspection of welding be supplemented with radiography at least for those connections on the hull which have proved critical in service.

* * *

By H. W. Pierce†

As a concise and very readable summary of the wartime experiences in the construction of all-welded ships, Mr. Foreman's paper is to be praised. On several conclusions, however, the writer either finds it hard to agree with Mr. Foreman or sees little economic justification in some of the steps which he proposes.

It is quite true that the percentages of various types of failure have been gratifyingly low and that some of the contributory reasons were unquestionably poor workmanship, errors in design, inferior materials and hard operation—all made worse by wartime conditions. It is possible that the end of hostilities and a more leisurely pace of construction with less inflated forces may reduce the instances of poor workmanship and bad design, but I seriously doubt if they can be wholly eliminated. This seems too optimistic to be fully accomplished.

For example, examination of almost any ship will reveal workmanship, and in some cases design factors, which seem as detrimental, theoretically, as those which have been specifically blamed for failure on other ships. The necessity for all manner of attachments for gear or devices used in the operation of the ship makes the removal of all hard spots and crack starters a superhuman task. If we assume that the most careful scrutiny of the drawings as well as the close inspection of completed work might accomplish even this, there is no assurance that at some future date alterations or additions will not be made by the crew, a repair yard or an impatient stevedore, which will create an equally bad situation. In one case of failure, a major crack started at a point on a hatch coaming where a wire cable had cut a severe notch. Ships simply must not be such fragile affairs that local damage, inadvertent or otherwise, can initiate a serious fracture.

The monolithic nature of the welded ship is at once one of its advantages and one of its greatest disadvantages. It has led us into a new field, for in these large structures rigid and highly indeterminate in design, behavior is not like the riveted ship with which we are more familiar. The writer is not so pessimistic that he believes the solution of this new problem is impossible. It simply must be recognized that at the present state of our knowledge and the materials available, together with human imperfections which will always exist, it seems we have little to lose and much to gain by providing definite means to stop or to arrest failures, at least at critical points. Neither does it appear that it is necessarily sound engineering to promote "the all-welded ship" as such. An engineer or designer in any field should use the means, the tools and the materials which are economically and technically correct for the job. In specific applications, plastics may be better than metal, castings better than intricate weldments and the writer still regards rivets as a better proposition in some parts of the ship structure than the rigid welded connection. The goal is to produce a ship which can be constructed and operated at the lowest possible over-all cost, all factors considered, and in the safest possible manner. To do this requires the sound use of every material and method known.

† New York Shipbuilding Corp.

Alternating and Direct Current Welding*

By Lee Cline†

WHEN we speak of alternating current from strictly a welding standpoint, we do not consider polarity because the current polarity is reversing twice each cycle, which is 120 times a second on a 60-cycle circuit. However, at any given instance, the polarity of an a.-c. circuit is of a certain polarity, either straight or reverse.

Direct current, of course, flows in a constant cycle, either straight or reverse polarity.

Until recently 85% of the welding in the United States was done with direct current. Seventy-five per cent of the electrodes being used today are E6010 type electrodes, which are designed for vertical and overhead welding on direct current only.

At present and for the past year, exceptionally good electrodes have been on the market for vertical and overhead welding with alternating current.

* Presented at the October meeting, Los Angeles Section, A.W.S.
† Welding Superintendent, Consolidated Steel Co., Shipbuilding Division, Wilmington, Calif.

These electrodes come under the classification of E6011 type electrodes. They meet all the requirements of E6010 electrodes and will either operate on a.-c. or d.-c. reverse polarity.

Due to the characteristics of alternating current it was necessary to add additional arc stability ingredients to take care of the so-called flat spot in the a.-c. arc as it reversed from straight to reverse polarity which caused the arc to have a tendency to die out.

Overcoming these conditions in the design of the E6011 type electrode gives the following advantages in using E6011 either on alternating or direct current.

1. Has higher deposit rate.
2. Higher operating efficiency.
3. Easier arc striking characteristics.
4. Arc is more difficult to extinguish.
5. Easier slag removal.
6. Not as sensitive to moisture variation.
7. Physical tests are about the same under identical conditions. Ductility is higher on a.-c. electrodes.

With the advantage of the E6011 type electrode it is now possible for welding operators to purchase a.-c. transformers as universal equipment for both large and small diameter electrode work.

It has been generally known, for some time, that for electrodes 7/32 in. and larger, alternating current has been the most satisfactory due to the elimination of arc blow and arc interference which increases with higher welding current.

We knew, as early as 1940, that alternating current was much more satisfactory for deep groove welding and flat horizontal fillet welding.

At that time we were planning our production program for the building of welded gun mounts, tanks, bombs, and many other wartime products. But, we were limited to the use of a.-c. equipment due to not having E6011 type electrodes available for vertical and overhead welding.

At that time we were only able to use a.-c. equipment on fabrication which could be positioned. *At present we have no limitation for the use of alternating current in the welding of mild steel and low-alloy steel in any position.*

Since Dec. 1, 1944, we have used 5,523,950 lb. of manual welding electrodes which were designed for operating on either alternating or direct current.

In addition we have used 385,960 lb. of wire in our automatic arc process which was also operated on alternating current. The above amount was used in the following sizes and electrode classifications:

1/8 in.	E6011	3%	1/4 in.	E6011	
			1/4 in.	E6012	
5/32 in.	E6011	19%	1/4 in.	E6013	21%
			1/4 in.	E6020	
3/16 in.	E6011		1/4 in.	E6030	
3/16 in.	E6013	43%			
3/16 in.	E6020		5/16 in.	E6013	
			5/16 in.	E6020	12%
7/32 in.	E6011	2%	5/16 in.	E6030	
7/32 in.	E6013				

We have welded 57 all-welded ships with electrodes designed for alternating current. This included all high-pressure piping. This work was subjected to inspection by the Maritime Commission, American Bureau of Shipping and the Bureau of Marine Inspection and Navigation.

At our Maywood Naval Ordnance Division we have welded 436 all-welded gun mounts using alternating current and 6030 type electrodes. This work was built to Navy Ordnance specifications and was subjected to Magnaflux and X-ray inspection.

All the above work has been highly satisfactory and no weld failure either minor or major has resulted from service operation.

In addition to the savings represented by increasing rod size and speed of application with the usage of alternating current there is the power and maintenance savings.

Our electrical engineering division has completed the following test between a 400-amp. m.g. d.-c. machine and a 500-amp. a.-c. welding transformer with both types of equipment operating on a 40% duty cycle and operating at 400 amp.

These tests showed that the d.-c. machine operated at 60% efficiency and the a.-c. transformer operated at 85% efficiency.

The above tests showed that the d.-c. set had a kilowatt-hour loss of 43 kilowatthours per 8-hr. shift, where the a.-c. transformer only had a kilowatt-hour loss of 16 kilowatthours per 8-hr. shift. Basing costs on a rate of 1¢ per k.w.h. these tests show a power saving of 27¢ per day in favor of the a.-c. transformer.

Basing this saving on a two-shift basis you have a power saving of approximately $150 per year when using alternating current. Also we find our maintenance cost on a.-c. equipment is approximately 10% of what it is on d.-c. equipment.

In conclusion, I feel safe in saying that over a 2-yr. period of operation your saving in power and maintenance cost would pay for a 500-amp. a.c. transformer.

Welded Redesign Brings Marked Improvements to Electric Meat Saw Machine

By J. S. McKeighan*

WITH reconversion in full swing, it is interesting to note that industrial designers are taking full advantage of welded type of construction to produce products that are not only superior in appearance, but are invariably stronger and more efficient in service.

By adopting the latest standard welding techniques and practices and by following the simple principles of designing approach, many concerns are already turning out trim appearing items of unparalleled efficiency in performance.

One outstanding example is shown in Figs. 1 to 4, inclusive, which illustrate the old and new designs of an electric meat saw machine made by The Kleen-Kut Manufacturing Co., Cleveland, Ohio. These views show the former unit of cast design which weighs 550 lb., as compared to the all-welded machine weighing only 350 lb.

Besides this important reduction in weight, the simplicity of arc-welded fabrication permitted the designers to incorporate significant features which increased overall rigidity and strength and eliminated a time-consuming tension adjustment. In the new design, for example, a deflection of less than $^1/_{16}$ in. has been effected in the top pulley support. This assembly is subjected to considerable stresses during operation of the saw. With welding, needed strength was obtained by simply welding a 32-in. length of angle vertically inside the blade and pulley housing and base frame to act as a stiffener.

* Mr. McKeighan is Welding Engineer located at the Lincoln Electric Co., Cleveland 1, Ohio.

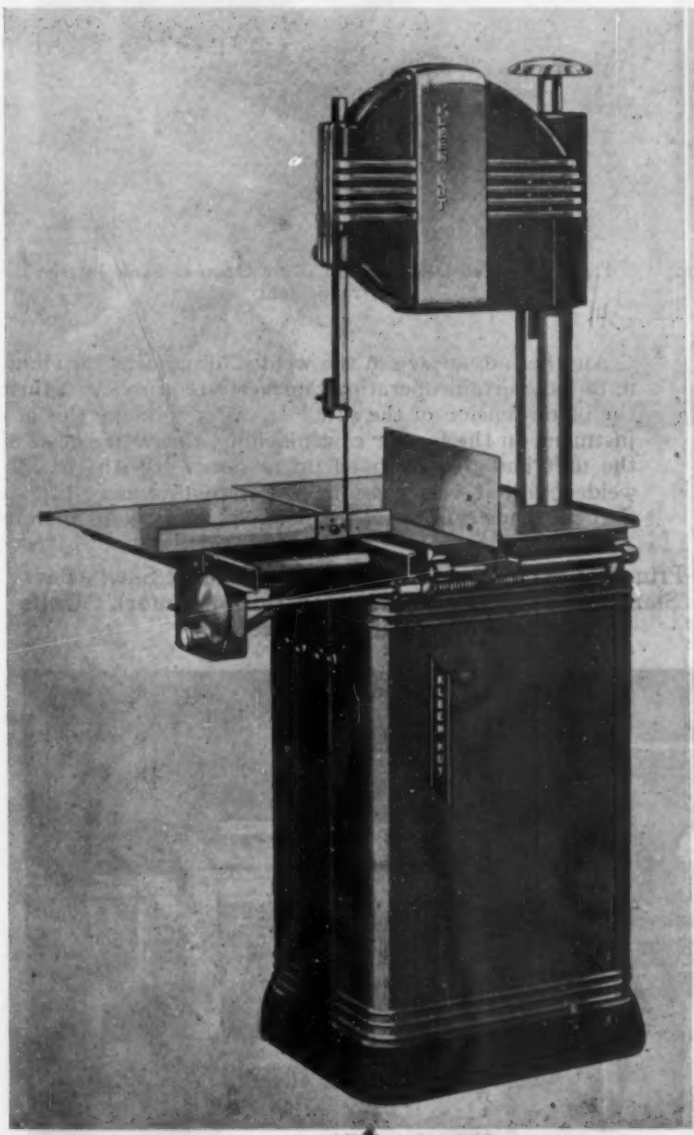


Fig. 1—View of Electric Meat Saw Machine Showing Previous Cast Design Weighing 550 Lb.

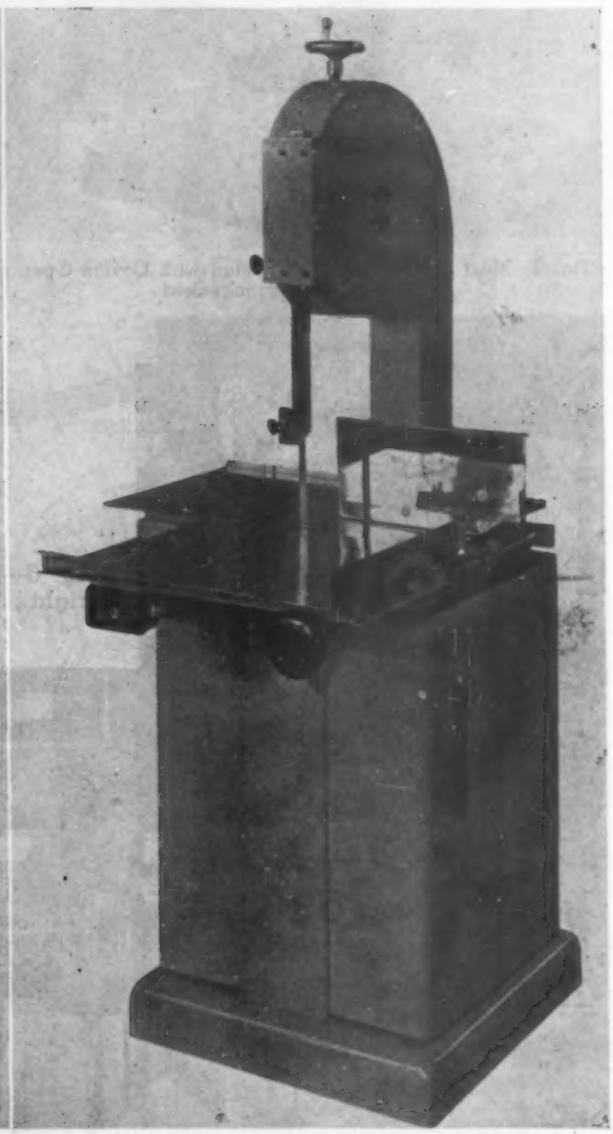


Fig. 2—New Arc-Welded Design Weighing 350 Lb.

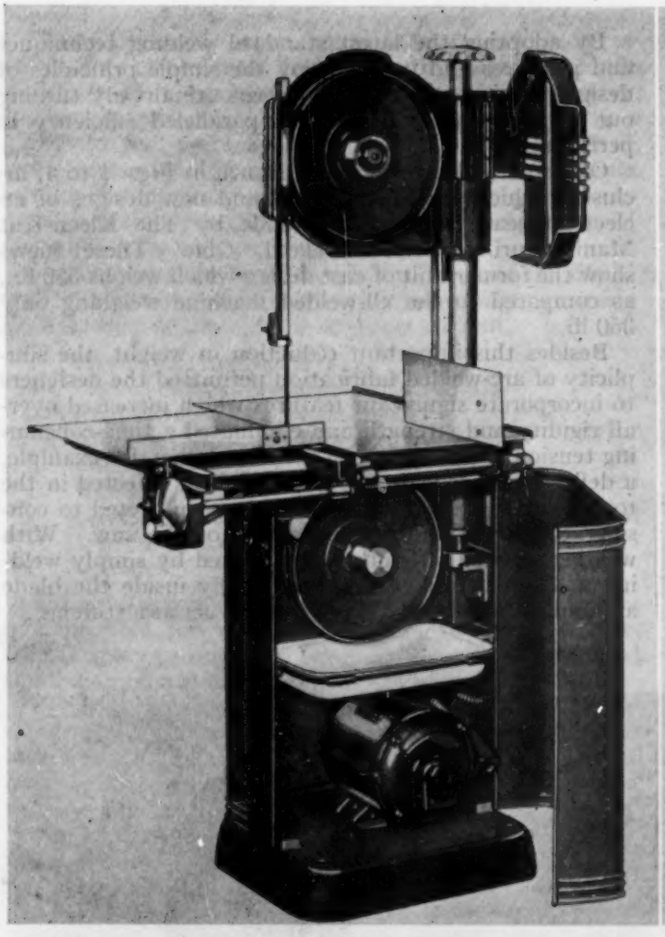


Fig. 3—Meat Saw Unit of Cast Design with Covers Open to Show Interior Arrangement

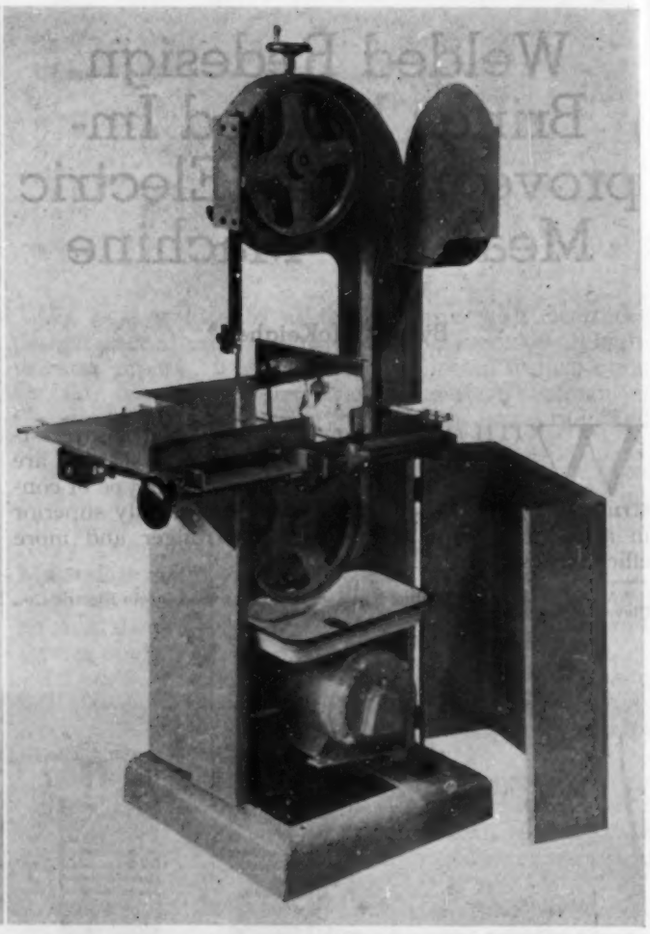


Fig. 4—Welded Design with Covers Open to Show Interior Arrangement

Another advantage in the welded design was the elimination of certain operations formerly required to adjust the blade tension of the saw. In order to make this adjustment on the former cast machine, the entire head of the unit had to be moved up or down. With the all-welded unit it was possible to design this assembly so that the blade tension adjustment can be made by merely

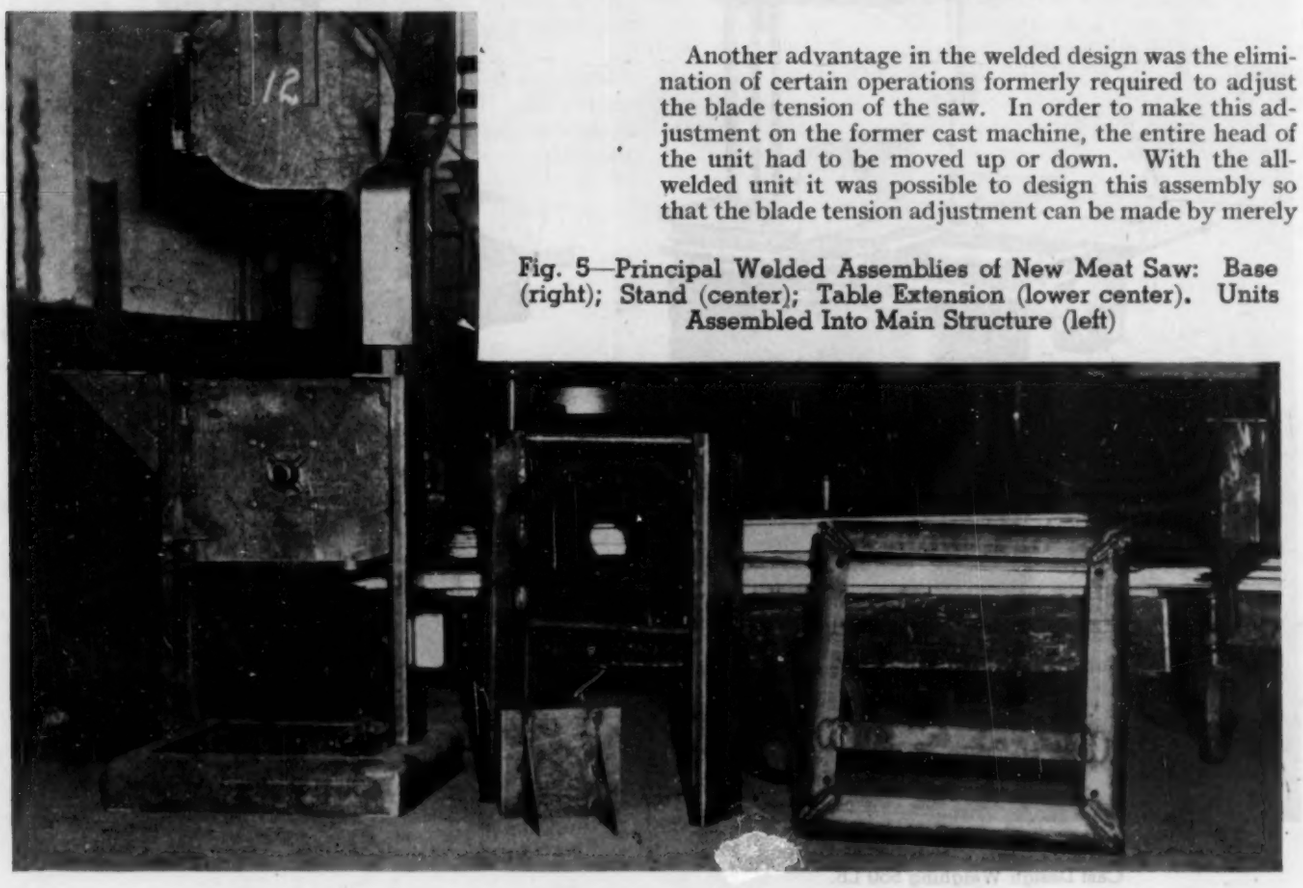
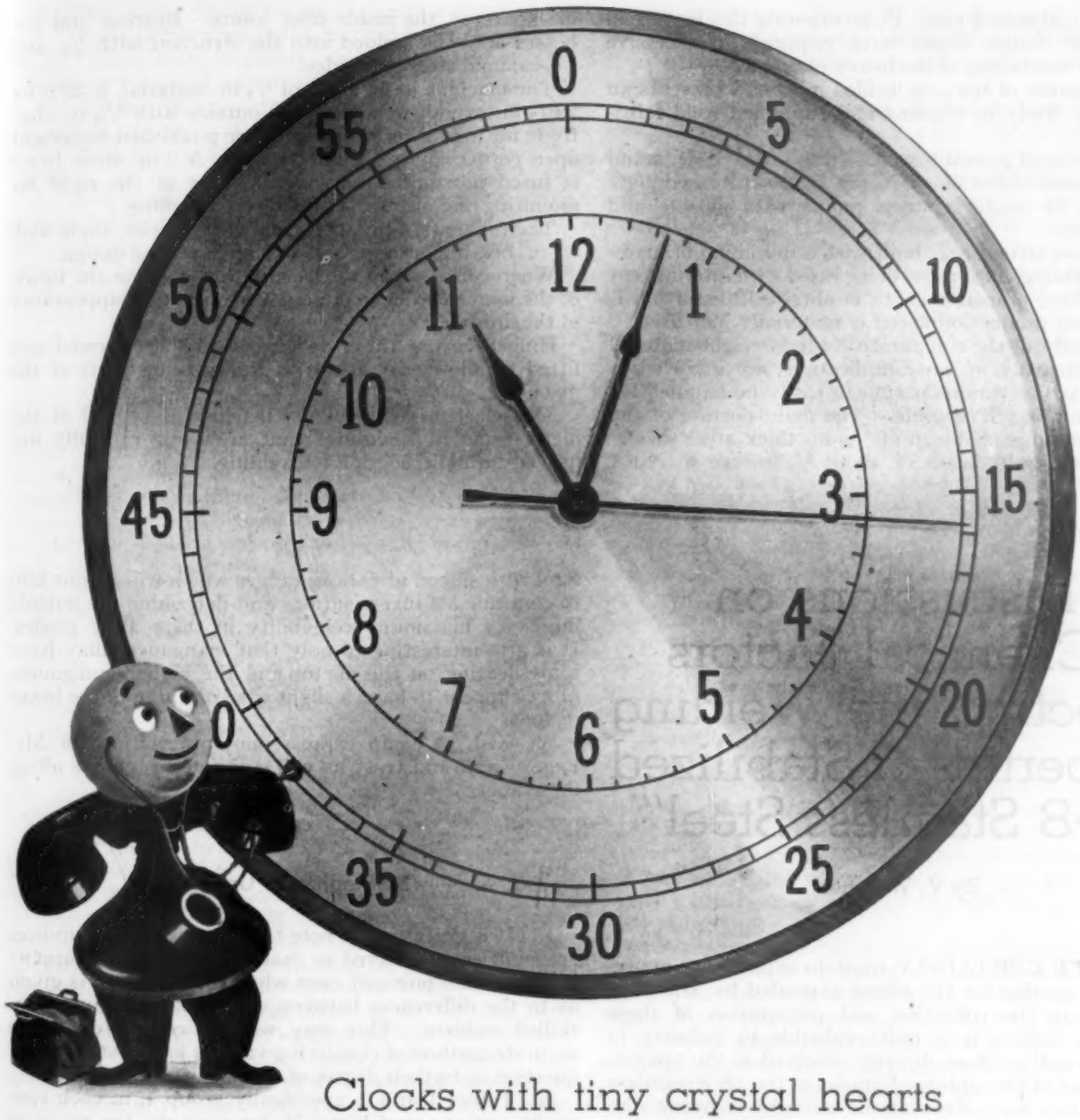


Fig. 5—Principal Welded Assemblies of New Meat Saw: Base (right); Stand (center); Table Extension (lower center). Units Assembled Into Main Structure (left)



Clocks with tiny crystal hearts that beat 100,000 times a second

CRYSTAL HEARTS beat time in Bell Telephone Laboratories, and serve as standards in its electronics research. Four crystal clocks, without pendulums or escapements, throb their successive cycles without varying by as much as a second a year.

Precise time measurements may seem a far cry from Bell System telephone research, but time is a measure of frequency, and frequency is the foundation of modern communication, whether by land lines, cable, or radio.

These clocks are electronic devices developed by Bell Laboratories, and refined over years of research. Their energy is supplied through vacuum tubes, but the accurate timing, the controlling heart of the clock, is provided by a quartz crystal plate about the size of a postage stamp.

These crystal plates vibrate 100,000 times a second, but their contraction and expansion is submicroscopically small—less than a hundred-thousandth of an inch. They are in sealed boxes to avoid any variation in atmospheric pressure, and their temperatures are controlled to a limit as small as a hundredth of a degree.

Bell Telephone Laboratories was one of the first to explore the possibilities of quartz in electrical communication, and its researches over many years enabled it to meet the need for precise crystals for a variety of war applications. In one application alone, radio sets for armored tanks, over ten million crystal plates have been utilized.

BELL TELEPHONE LABORATORIES *Exploring and inventing, devising and perfecting for our Armed Forces at war and for continued improvements and economies in telephone service.*

turning an adjusting rod. To incorporate this feature in the former design would have required an excessive amount of machining of the heavy castings.

Manufacture of the new welded meat saw presents an interesting study in efficient and simplified weld fabrication.

The principal assemblies consisting of the base, stand and table assemblies shown in Fig. 5, are of formed plate reinforced at strategic stress points with gussets and cross braces.

The entire structure is built with a minimum of material and welding, most parts being fused with intermittent welds. Thus, proper strength is obtained, distortion is avoided and production speed is materially increased.

Due chiefly to the comparatively lightweight material used in construction, no complications are involved in assembly as the various parts can easily be handled for welding on a bench or table. The main portion of the machine stand is made up of $^3/_{16}$-in. thick steel sheets. Intermittent weld beads of about $^3/_4$ in. are spaced 4 in. apart at the inside fillet joints. Bearing and pin bosses are solid welded into the structure with $^1/_8$- and $^5/_{32}$-in. mild steel electrodes.

The machine base, made of $^1/_4$-in. material, is $22^1/_2$ by $22^1/_2$ in. overall welded on the outside with $^5/_{32}$-in. electrode for mild steel. The parts are positioned to present open corner joints for fillet welds. A 2-in. strap brace is fused horizontally across the base at the right for mounting the electric motor of the machine.

The table assembly, constructed of $1^1/_2$-in. angle with $^1/_2$-in. bearing brace, is also of simple welded design.

Wherever possible, the welding was done on the inside of the joint in order to present a smooth, neat appearance of the finished job.

Hinged covers are of 14 gage steel sheet formed and fitted to allow easy access to the working parts of the machine.

This electric meat cutting machine is typical of the many types of structures that are being radically improved through redesign for welding.

Discussions on "Chemical Factors Affecting the Welding Properties of Stabilized 18–8 Stainless Steel"*

By V. Whitmer†

WE CERTAINLY want to express our appreciation for the efforts expended by Mr. Page in the collection and preparation of these data. We believe it is quite valuable to industry in general as well as those directly involved in the production and use of the stabilized grades of the 18–8 stainless alloys to have such observations made by someone who is handling these alloys day in and day out in comparatively large volume as does the Solar Aircraft Co.

It has been generally accepted in the past, though probably for no particular reason, that silicon has been held under 0.50% as a general average for these alloys. There is one grade of 18–8 produced with high silicon in the range of 2.0–3.0% with or without stabilizing alloys primarily for heat resistance which does weld with entirely different characteristics than the same type without high silicon. To our knowledge, however, this is the first observation by anyone to detect measurable differences in silicon content in the low ranges, say under 0.75%.

We feel there is no doubt from the facts Mr. Page has presented in a very clear manner that some advantages are to be gained with the higher silicon ranges. This is not surprising as silicon is a very good deoxidizer. In that role it should serve to give cleaner welds in the presence of such an oxidizable element as titanium.

We certainly hope Mr. Page will continue to receive steel with silicon in various ranges which will permit him to continue his investigations and determine the outside limits for maximum weldability in these alloy grades. It is also interesting to note that manganese may have some bearing on this factor and the higher manganese ranges appear to have a slight edge on those in the lower regions.

We wish to again express our appreciation for Mr. Page's work and trust he will continue his efforts along these lines.

* * *

By Stephen F. Urban‡

1. It is gratifying to note that the weldability indices are sufficiently selected so that there is not overlapping by more than one unit even when consideration is given as to the differences between skilled and relatively unskilled welders. This may well be considered as an accurate method of classifying various lots of steel under question as to their degree of weldability.

2. Tables 1 and 2, specifically group I, in each case might perhaps read better if, for example, the range of titanium and carbon were shown rather than 0–0.41 and 0–0.052, respectively. It is realized that this may make good sense to a statistician; however, it contraverts facts, namely, that it is impossible to make a steel of 0% carbon.

3. Since Tables 3 to 8, inclusive, refer to oxyacetylene welding, it is presumed that this also applies to Tables 1 and 2.

4. The importance of obtaining a uniformity in welding index from lot to lot is very well expressed by Mr. Page in that, as he has stated, the welder will automatically weld at a rate commensurate with that of the poorest welding steel.

5. The correlation between increasing manganese and silicon contents and increasing weldability indices seems to have some fundamental basis. For example, it is known that very low fusion points are obtained in certain regions of the $FeO–MnO–SiO_2$ system, which fusion points are lower than are obtainable in any of the binary combinations. This was first brought out by Dr. Herty and co-workers and has since been confirmed by other investigators. Therefore, it appears that the

* Submitted by Mr. Franklin H. Page, Jr., of the Solar Aircraft Company, San Diego, Calif., and published in the October issue of THE WELDING JOURNAL.

† Stainless Metallurgical Engineer, Republic Steel Corp., Central Alloy District.

‡ Director of Research, The Titanium Alloy Mfg. Co.

weldability index should be more closely related to the Mn:Si ratio rather than to the manganese or silicon contents. This is a crude analogy and cannot be translated directly to a system containing probably chromium and nickel oxides. In any event it is doubtful that the same correlation would exist if a coated rod were employed rather than the flange type of welding described in the paper.

6. It is gratifying to note that under precise conditions of welding there is no particular difference between the titanium and columbium stabilized grades which heretofore has been an issue clouded by much opinion and little fact.

* * *

By G. F. Comstock†

The evidence presented by the author on the promotion of good weldability in stainless steel sheets by high silicon content is certainly convincing, but it is not clear from the data in Table 3 why carbon is not mentioned in the text, along with manganese and titanium, as "having a lesser effect." The correlation of the carbon composition groups with the average weldability indices seems better than that of the manganese groups in the tables. Thus not only higher silicon, but also higher carbon, manganese and titanium, seem in general to promote better weldability.

All of these elements are deoxidizers, so that the author's assumption that silicon is effective because of its deoxidizing action seems reasonable. Aluminum, however, is the strongest deoxidizer of all, yet the correlation of aluminum with weldability is shown to be very poor. This would be a very serious objection to an explanation of the effect of silicon based on deoxidation, unless it should happen that the author's values for aluminum content represent total aluminum, including oxide. This should be reported, because then the deoxidation theory might be valid, and a higher aluminum content might mean merely that more aluminum oxide happened to be trapped in the steel where the sample for analysis was taken. It could then be assumed, on the basis of these data, that the heats with better weldability were more thoroughly deoxidized in the furnace with aluminum than the others, so that the other deoxidizing elements, including silicon, manganese, carbon and titanium, were recovered in the finished product in greater amount. Less segregation of titanium carbonitride would also be expected in such heats.

If the author's values for aluminum represent residual metallic aluminum only, however, this theory could not be correct, and the effect of silicon in promoting weldability would have to be explained in some other way than on the basis of deoxidation, because aluminum is a much stronger deoxidizer than silicon. The reason might be that the higher silicon lowers the melting point of the steel enough to give an improvement in fluidity, or it may produce a change in surface tension, or help to flux chromium oxide, but these suggestions are pure speculation.

* * *

Author's Reply to Comments of Dr. Stephen F. Urban

I agree with Dr. Urban that it does not make very good sense to refer to a range of titanium contents as being from 0–0.41 or carbon from 0–0.052 as it is obviously impossible to make a Type 321 stainless steel with 0 titanium or any steel with 0 carbon, or for that matter 0 sulfur or 0 phosphorus. What is meant, of course, is that any steel with 0.052 or less carbon belongs in the carbon correlation, Group I. This is one of the pitfalls which lies in the way of a chemist or metallurgist who tries to masquerade as a statistician for purposes of analyzing his data.

I am not at all sure of the mechanism by which manganese and silicon improve the weldability of stainless steel. The explanation for silicon's effect which seems most logical to me credits its usefulness as a deoxidizer but its slagging characteristics are also obviously important. This is also shown in work which we have done on welding fluxes on which it is indicated that a slight change either in the manganese or silicon content of the flux can have a marked effect upon weldability. It should be noted parenthetically that about the same relative weldability relationships hold between heats of steel regardless of the flux used. If steel "A" welds more easily than steel "B" with one good flux, "A" will weld more easily than "B" with any other flux or with no flux at all.

I have attempted to go over my original data and calculate the manganese to silicon ratio of the steels and to attempt to correlate this ratio with the welding properties. A strong negative correlation was discovered—that is, steels with a low manganese-silicon ratio had uniformly better welding properties than steels with a high manganese-silicon ratio. This observation is perhaps not too significant as there was a much greater proportionate spread of silicon contents in the steels investigated than of manganese contents and most of the steels with high silicon contents had low manganese to silicon ratios, so it may be that we are merely looking at the silicon content expressed in another manner. In analogy, we might attempt to correlate the weldability with the iron-silicon ratios and would discover a strong negative correlation. This correlation would, however, be meaningless as the iron content is practically identical in every sample investigated. This still leaves unsolved the problem of the mechanism of silicon's and/or manganese's beneficial effect upon the welding properties of 18–8 stainless.

Dr. Urban has concluded from the data the same thing that we had discovered not only in the laboratory but in the production shop regarding the difference between titanium and columbium stabilized stainless steel. That is, with the proper silicon and manganese content and with welders who are experienced with either material, there is little to choose between them on the basis of welding properties.

* * *

Author's Response to G. F. Comstock's Discussion

Mr. Comstock has found a valid correlation between carbon content and weldability of stabilized 18–8 stainless steel. I did not call attention to this correlation in my paper as it might be misinterpreted as encouraging higher carbon contents which sometimes may have unfavorable effects on the corrosion resistance of the welded assembly.

It might also be mentioned that a great number of correlations were made which could not be noted in the paper without greatly increasing its length. One of these correlations demonstrates that the effect of carbon is not nearly as strong in samples containing more than 0.50% silicon and the carbon content is thus not as effective in the preferred higher silicon ranges.

Mr. Comstock is correct in his assumption that the lack of correlation with aluminum may be due to recording total aluminum. Our analytical data for aluminum are entirely spectrographic which I do not believe differentiates between metallic aluminum and aluminum oxide.

† Chief Metallurgist, The Titanium Alloy Mfg. Co., Niagara Falls, N. Y.

Discussion of Paper, "Electric Eye Tracing in Machine Cutting"*

By C. M. Underwood†

IN MOST fabrication shops there is a very real need for accurate gas cutting of shapes and parts to be fabricated. Variations in cutting frequently cause varying kerf sizes with resulting inconsistencies in shrinkage and distortion of the finished product. Variations in cutting frequently cause poor setups and require an excessive amount of welding to produce a satisfactory joint. The result is a material increase in the cost of finished products.

In order to avoid these defects it is frequently necessary to employ mechanically guided equipment. The means of mechanically guiding commercial torch-cutting equipment is fairly elaborate and too expensive to employ unless there are a number of parts to be produced. The need for an accurate and inexpensive method of torch guiding has long been desired in most fabrication shops. The equipment described by Mr. Begerow apparently meets the requirements for accurate cutting and no longer requires expensive fixtures. The application of this principle should be universally accepted.

Further, the equipment appears to have possibilities for the application of beveling to irregular shaped pieces. The welding torch holder illustrated in Fig. 1 permits the rotation of the torch about a vertical axis. The torch may be adjusted horizontally and also in the line of the torch axis. The torch axis may also be turned to any angle. Thus with this unit it is possible to set a torch to cut any desired bevel on an irregularly shaped piece by moving the vertical axis of the unit along the contour of the shape being cut and at the same time rotating the torch so that the flame is normal to the edge of the piece at the point being cut.

By extending the powered jack shaft which drives the pickup unit and tracing head, a similar connection could be made to the torch holder unit which would permit the interlocking of all three units so that the torch would not only follow the contour made by the tracing head but would rotate to duplicate the angular motion of the pickup unit. With this simple arrangement it would be possible to build a unit which not only can accurately cut irregular shaped parts but can put any desired bevel on these shaped parts with equal ease.

* * *

By E. D. Debes†

The device which is in operation in the shops of Air Reduction Sales Co. at Jersey City have been inspected by a representative of our company, and I have been advised as follows:

"Why, the thing is uncanny! However, it does all that Mr. Begerow's paper claims and is simple to operate. It was noticed that allowance had to be made for the 'kerf' in preparing the drawing if the accuracy possible with the machine is necessary. This is in accordance with Paragraph V of the paper. In other words, special drawings have to be made in such cases based on experience obtained in actual operation as to the amount of 'kerf' adjustment. It is felt that there is a great field for this equipment, particularly where intricate specimen has to be cut and where sharp corners are required. For simple specimen, such as flanges cut in great quantities, the magnetic tracing device would be hard to beat as the cast of the template is very low and there are no sharp corners to contend with."

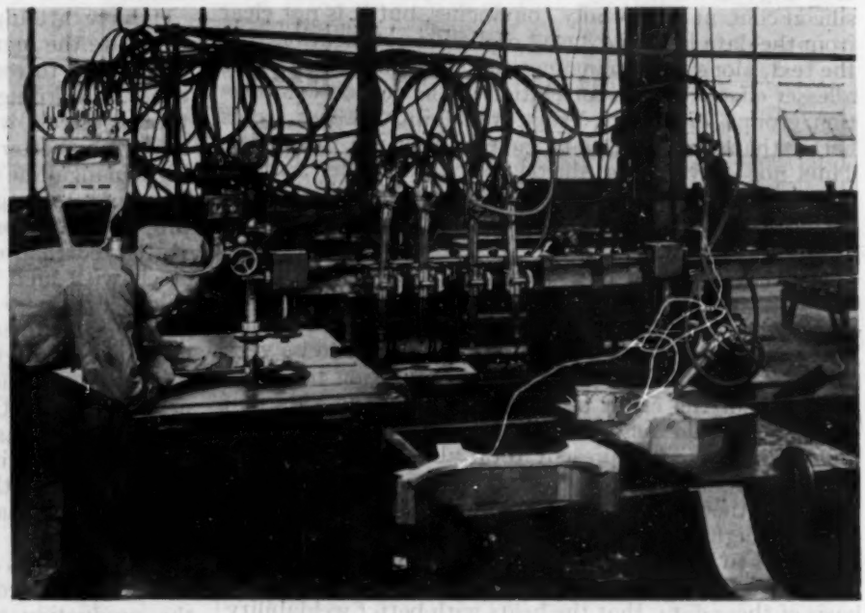
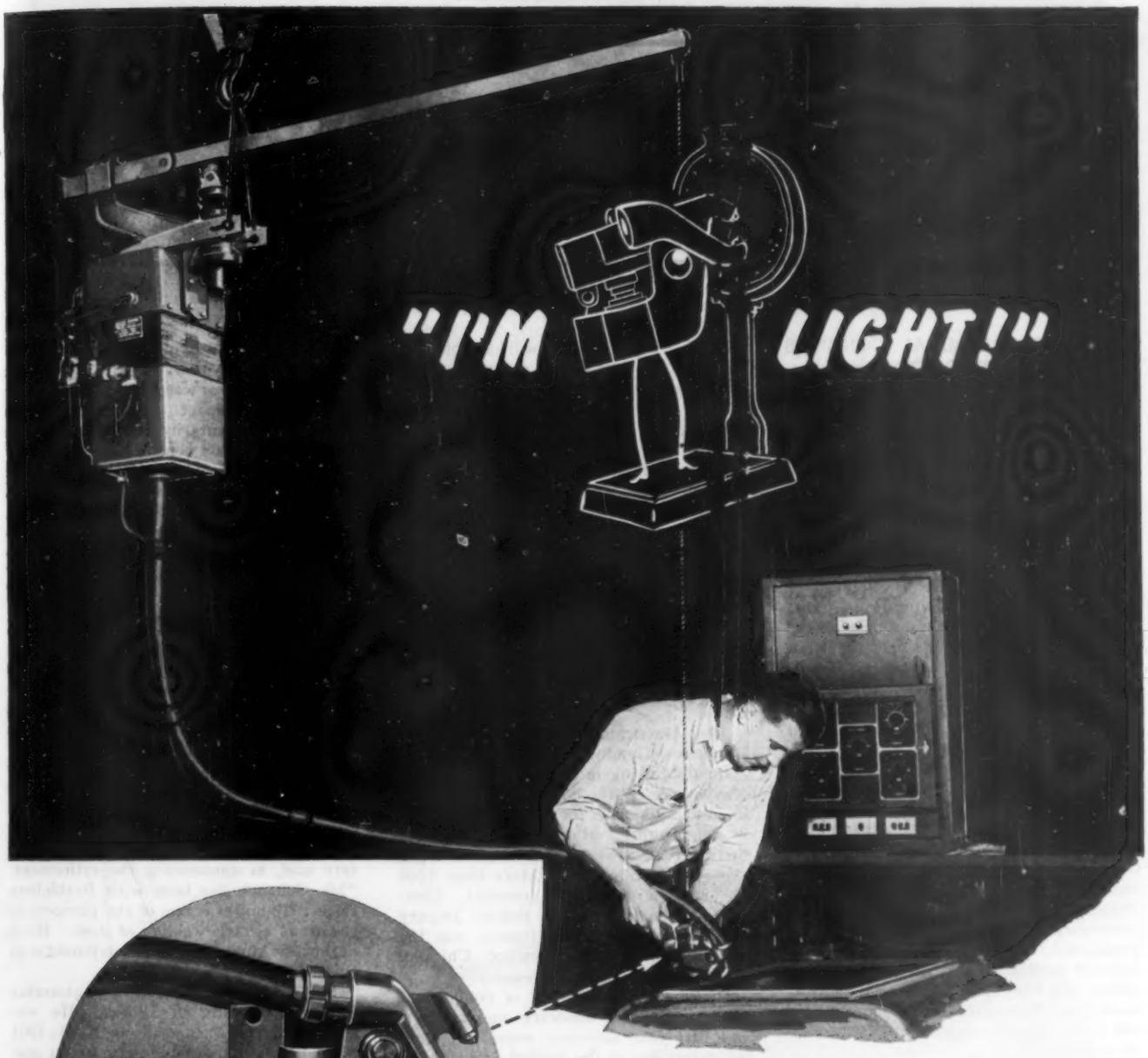


Fig. 1

* Paper by Walter Begerow published in the October 1945 issue of THE WELDING JOURNAL.

† Manager, Welding Dept., Northern Ordnance Inc., Minneapolis, Minn.

† Welding Engineer, Bethlehem Steel Co., Shipbuilding Div., Quincy, Mass.



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ACTIVITIES – RELATED EVENTS

27TH NATIONAL METAL CONGRESS AND EXPOSITION

Largest attendance in history is predicted for the 27th National Metal Congress and Exposition to be held in Cleveland's Public Auditorium the week of Feb. 4th through 8th.

"Every indication points to an attendance in excess of 30,000 industrial visitors," stated W. H. Eisenman, managing director of the event, and national secretary of the American Society for Metals, sponsor of the Congress and Exposition. "One attendance barometer is the size of the Exposition itself. With some 350 leading manufacturers of metals, equipment, supplies and services participating, this will be the largest industrial show ever held, 25% larger than the big show held in Cleveland in 1944.

"The metal industry will see many products and production techniques that have never before been available for peacetime use. Always the outstanding event of the year in the metal industry, this show will have particular interest and significance because many exhibitors will introduce wartime developments and demonstrate their application to civilian production. Occupying more than eight acres of display area in the Public Auditorium and Underground Exposition Hall, more than 1500 executives and engineers will be on hand to consult with visitors to the exhibits."

Housing conditions in Cleveland during the week of the Show will be crowded but hotels have given assurance of every cooperation in taking care of out-of-town visitors. To facilitate room reservations, the Cleveland Convention and Visitors' Bureau, 1604 Terminal Tower, has established a Housing Bureau to secure accommodations in hotels, apartments or private homes. Visitors may make advance reservations by writing the Housing Bureau or may apply for accommodations upon arrival at leading Cleveland hotels or at the Public Auditorium where temporary offices will be established by the Bureau.

Widespread interest in the Metal Congress has also developed from plans for business and group meetings of technical societies and by the daily technical program featuring more than 100 engineering experts in the presentation of some 70 lectures and research papers.

In addition to the technical program of the American Society for Metals, papers will also be presented by the American Industrial Radium and X-ray Society meeting at Hotel Hollenden on Wednesday, Thursday, and Friday, Feb. 6th, 7th and 8th. Other societies will have business or group meetings during the week.

Presentation of four medals will be a feature of the annual dinner of the American Society for Metals, Thursday, Feb. 7th, in the Grand Ballroom of Hotel Statler with the award of the Henry Marion Howe Medal for the paper of the highest merit published in *Transactions* during the year 1944; the Albert Sauveur Achievement Award, the ASM Medal for the Advancement of Research and the ASM Gold Medal.

A.S.M.E. PRESENTS HONORS AND AWARDS AT ANNUAL DINNER

The American Society of Mechanical Engineers, holding its four-day 66th Annual Meeting in New York (Tuesday, November 27th), conferred its annual honors and awards for distinguished work in engineering, education, research or literature, at a dinner and honors night event at Hotel Astor. More than 1500 members and guests attended. Lieutenant General Ira C. Eaker, Deputy Commander, Army Air Forces, was the speaker. Alex D. Bailey of Chicago, president of the Society, presided.

Represented on the list of honors and awards winners, honorary memberships and fifty-year members were men from many sections of the United States, east, far west, middle west and south, and from four of the United Nations, England, Canada, China and Norway.

William F. Durand Honored

The A.S.M.E. Medal, the Society's highest honor, this year was awarded to Dr. William Frederick Durand, professor emeritus of mechanical engineering, Stanford University, Calif. This award, given for distinguished service in engineering and science, was presented in recognition of his work in forwarding the design and application of principles of jet propulsion and for his effective leadership of the division of engineering and industrial research, National Research Council, of which he is the former chairman.

Dr. Durand is a member of the AMERICAN WELDING SOCIETY.

The Holly Medal, presented for "some great and unique act of genius of an engineering nature," was awarded to Dr. Sanford Alexander Moss, General Electric Engineer of West Lynn, Mass., for his many contributions to the development and application of turbosuperchargers to internal combustion engines. Retiring in 1938, Dr. Moss was in London the day of the Munich pact. Returning to this country he voluntarily resumed work, at the age of 67, as a consulting engineer for General Electric. In 1942, when he was 70, General H. H. Arnold sent greetings in behalf of the Army Air Forces, saying: "Your contribution of the airplane supercharger and turbosupercharger is outstanding in the science of aeronautics."

CHARLES SCHENCK RETIRES

Retirement of Charles Schenck, engineer of development, Bethlehem Steel Co., has been announced by R. S. A. Dougherty, manager, research department.

"It is with sincere regret that we accept Mr. Schenck's decision to retire from active participation in the Bethlehem Steel Co. research organization," Mr. Dougherty said, in announcing the retirement. "Mr. Schenck has been with Bethlehem since 1918 and was one of the pioneers in the art of electric welding of steel. He is nationally known for his contributions in this field."

Mr. Schenck studied civil engineering at the University of Illinois. He was employed by Chicago firms until 1901 when he was made an instructor in mechanical drawing and surveying at the Lewis Institute, Chicago, now the Illinois Institute of Technology. He became superintendent of the car shops of the Chicago Railways Co. in 1908, continuing there until 1910.

In 1910 Mr. Schenck became works manager and chief engineer of the Elevator Supply Co. of Chicago and Hoboken, N. J., and in 1916, works manager for Budd Wheel Co. of Philadelphia, then manufacturing wire and disk wheels for pleasure cars and trucks.

Mr. Schenck left the Budd Company in 1918 to become production engineer with Bethlehem Steel Co. at the Bethlehem plant, in charge of planning, estimating cost of machinery and piece work. He remained in this position until 1934, when he was appointed engineer of development in the development and research department, on special equipment, and consultant in manufacturing and welding.

Early interested in the possibilities of electric welding, Mr. Schenck, throughout his association with Bethlehem Steel Co., has made many contributions to the de-

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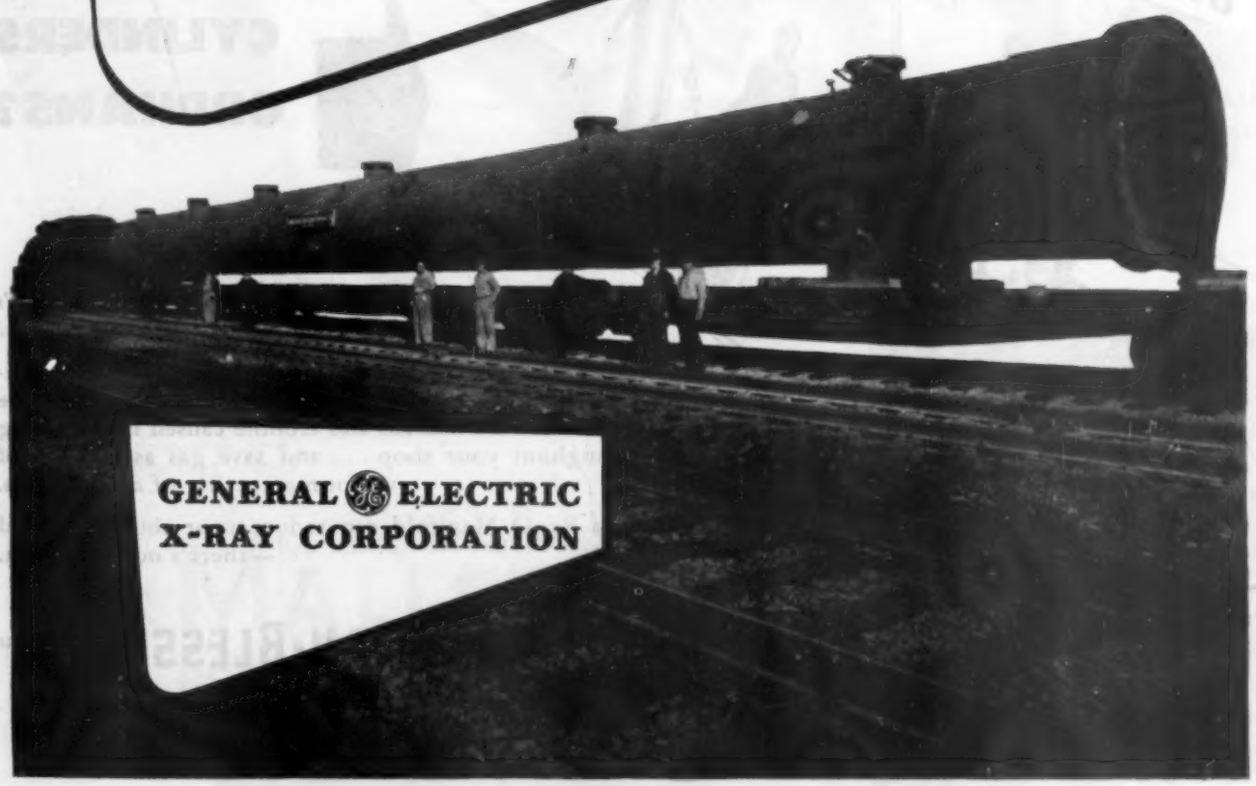
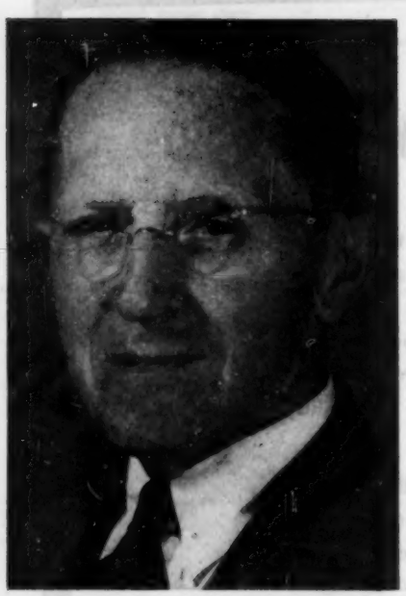




Charles Schenck

velopment of this method as a means to speedier and more efficient fabrication and construction. He was interested, too, in the important field of repair welding in many of its applications.

Mr. Schenck holds membership in the American Iron and Steel Institute, American Society of Mechanical Engineers, American Welding Society and Lehigh Valley Engineers Society. He is also a member of the Bethlehem Club and Saucon Valley Country Club.

Mr. Schenck will continue to do a moderate amount of manufacturing and welding consulting work for different firms desiring assistance in these fields.

AXTELL JOINS PROGRESSIVE WELDER

H. B. Axtell has joined with V. A. Chern to represent Progressive Welder Co., 3050 E. Outer Drive, Detroit 12, Mich. in the Eastern District, according to an announcement by L. M. Benkert, General Sales Manager of the company.

Mr. Axtell, for over ten years identified with resistance welding in the East, Far West and Mid-west, brings to the organization a wealth of experience in both the design of equipment and the application of welding processes in a wide range of industries. During the war he was largely responsible for the setting-up of many of the welding processes in plants faced with the conversion to products requiring the highest production methods. As Progressive's representative he will continue to offer field engineering services on resistance welding to manufacturers in the New York area. Mr. Axtell is a member of the American Welding Society.

Axtell and Chern have established offices at 15 Gramercy Park S., New York 3, N. Y.

THREE PROMOTED AT EAST PITTSBURGH PLANT

C. P. Croco, manager of the Welding Department in the Motor Division of the Westinghouse Electric Corp., East Pittsburgh, Pa., has announced the appointment of three employees to other posts in that department.

Charles H. Jennings, internationally known arc-welding expert and director of all welding research for the past nine years, becomes engineering manager of the Welding Department. John H. Blankenbuehler is made manager of arc-welding apparatus, while E. Hill Turnock, Jr., is made manager of arc-welding electrodes.

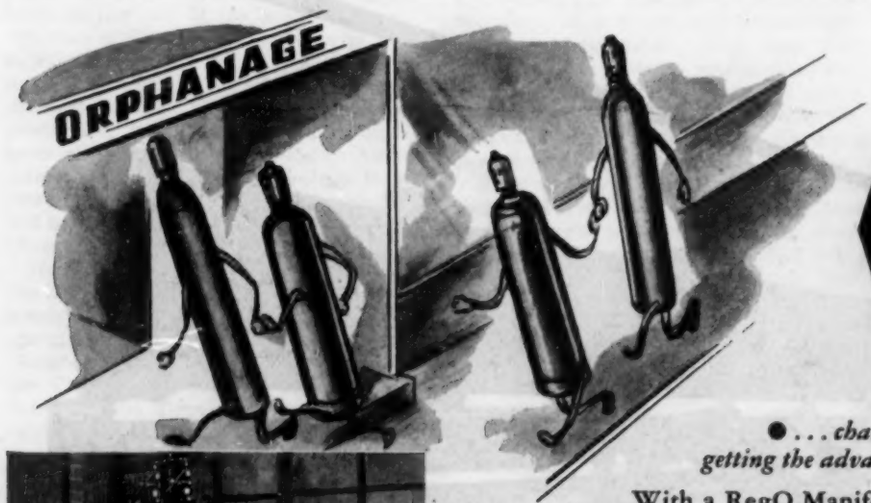
Born in Des Moines, Iowa, Mr. Jennings received a Bachelor of Science degree in mechanical engineering from Iowa State College, at Ames. He enrolled in the Westinghouse Graduate Student Course upon graduation in 1928, completing the normal year's study in seven months.

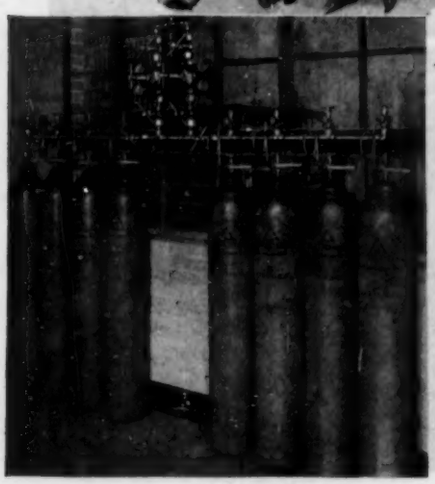
Has Wide Experience

Assigned to the mechanical division of the Research Laboratories, Mr. Jennings instituted advanced studies in the properties of welds and in welding design, applications and problems. He was transferred to the chemical and metallurgical division of the Laboratories and took charge of all welding research in 1936.

During his 17 years with Westinghouse,

(*Continued on page 66*)





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1. Use the proper electrode material for doing the job.
2. Use standard electrodes wherever possible.
3. Use the most suitable tip diameter for the thickness of stock being welded.
4. When in doubt, check the Mallory Resistance Welding Data Book.

DON'TS

1. Never use unidentified electrodes or electrode materials.
2. Avoid special, offset or irregular tips when the job can be done with a standard straight tip.
3. Don't use small tips on heavy gauge welding jobs or large tips on small work.

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(*Continued from page 62*)

Charles H. Jennings

Mr. Jennings conducted a course in welding metallurgy at the Carnegie Institute of Technology, prepared a training course for welding operators for the Pittsburgh Board of Education, and has written numerous articles on welding in addition to two books—*How to Weld 29 Metals* and *41 Lessons in Arc Welding*.

In 1937 Mr. Jennings was called to England as consultant welding engineer for the English Electric Co., and in the same year supervised all electric welding on the famed Westinghouse "atom-smasher." He was awarded the company's Order of Merit for distinguished service in welding research and application.

He belongs to the AMERICAN WELDING SOCIETY and is a director of that organization.

A native of Elizabeth, Pa., Mr. Blankenbuehler attended Elizabeth High School and was graduated from Lehigh University, Bethlehem, Pa., in 1923 with a degree in Electrical Engineering. He joined Westinghouse immediately as a student in the training course, became a design engineer, and has specialized in the design and development of welding apparatus and equipment. Mr. Blankenbuehler was awarded the company's Order of Merit in 1936 for his outstanding engineering work in the development of welding apparatus. He is a member of the American Institute of Electrical Engineers and the AMERICAN WELDING SOCIETY.

Electrode Production Specialist

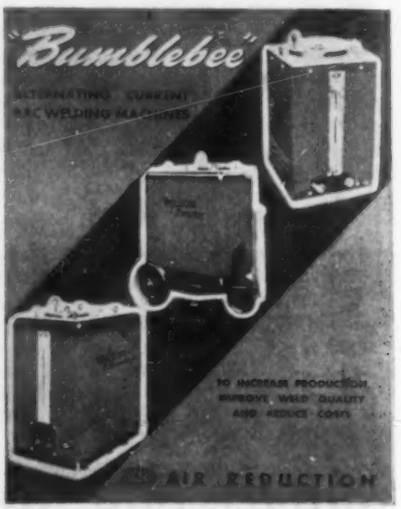
Born in La Grange, Ill., Mr. Turnock attended Elkhart, Ind., High School, the University of Wisconsin and Carnegie Institute of Technology, receiving his Bachelor of Science degree in chemical engineering in 1918. He served as a second lieutenant in the Army Engineers in France during World War I. Joining Westinghouse in 1926 as an insulation engineer, he was assigned to the development of welding electrodes a decade ago. Mr. Turnock, who won the company's Order of Merit award last year, is a member of the AMERICAN WELDING SOCIETY.

A.-C. ARC-WELDING MACHINE BOOKLET

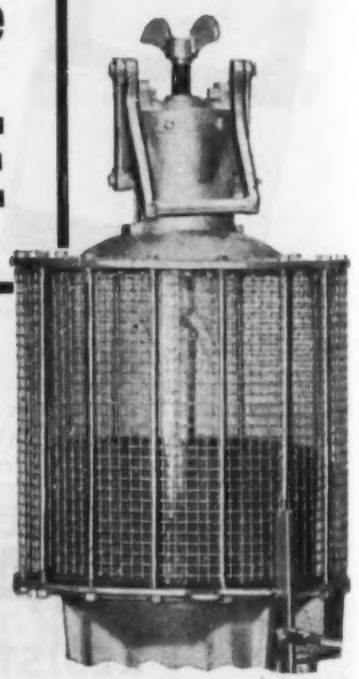
New and improved Wilson "Bumblebee" alternating-current transformer arc-welding machines are described fully in a 16-page illustrated booklet just published by Air Reduction, New York City.

Among the machines described are the 300- and 500-amp. standard and all-weather models, and the new 200-amp. "Bumblebee," which has been designed to meet the demands for a small arc welder comparable in performance with the big "Bumblebees."

Additional sections are devoted to small



Sight Feed is more than a TRADE NAME



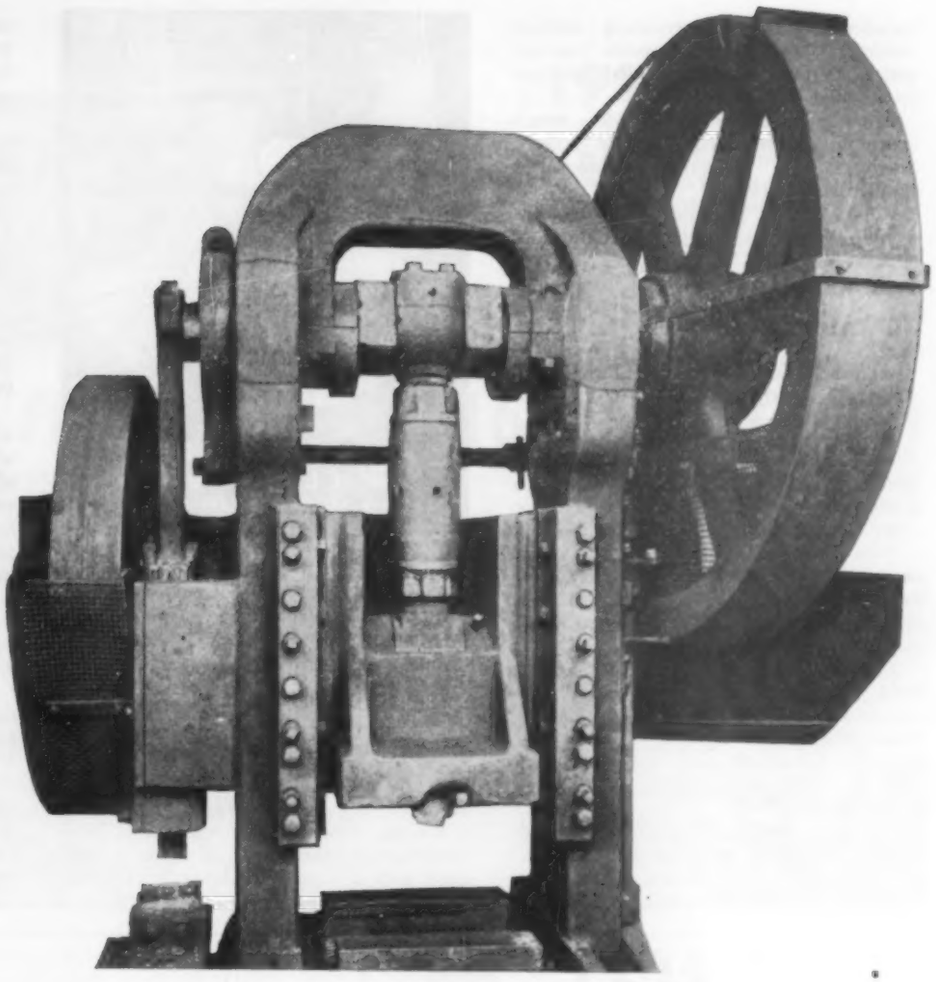
● It's true that "Sight Feed" is the name of one of the finest acetylene generators on today's market. But "Sight Feed" is also descriptive of an outstanding feature of this generator: the completely transparent Pyrex hopper which holds the carbide.

A glance at this hopper before you start a welding job will instantly tell you how much acetylene you may expect from your latest "charge." No guesswork—no "running out of heat" in the middle of a job—and the feed is entirely automatic.

"Sight Feed" acetylene is purer, hotter—yet it costs only a *fraction* of what you pay for "bottled" acetylene. Can you afford *not* to buy a "Sight Feed"?

Contact your jobber, or...

THE SIGHT FEED GENERATOR COMPANY • RICHMOND, INDIANA



35 hours for chipping and preheating, and 11 for welding with Anaconda "997" Low Fuming Rod, put this press frame back in operation.

Don't wait Months for Replacement

...BRONZE WELD it in *Hours!*

EVEN on a bad break like this one, Bronze Welding can save weeks, perhaps months, of waiting . . . and in addition, the heavy cost of new replacement parts.

Bronze Welding is quick, economical, practical. You save on preheating and annealing time, and also on oxygen and acetylene.

Because of the lower temperatures employed, no serious stresses are set up, there is less possibility of warping or cracking, parts can often be welded without dismantling equipment, and intricate sections of cast or malleable iron, steel and copper alloys can be joined quickly and economically.

In addition to Tobin Bronze* and "997" Low Fuming, Anaconda Welding Rods are available in a range of compositions suitable for almost every gas or electric Bronze Welding purpose. For detailed information, write for Publication B-13, "Anaconda Welding Rods." 46198

*Reg. U. S. Pat. Off.

ANACONDA

Anaconda

BRONZE WELDING RODS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD.
New Toronto, Ont.

transformer - type alternating - current welders, running gear, remote control, and a complete line of shielded arc electrodes for a.-c. welding.

Engineering data and complete specifications are supplied. Precise labeled drawings and numerous photographs supplement the text.

Copies of the "Bumblebee" booklet are available upon request to Air Reduction, 60 East 42nd St., New York 17, N. Y., or to the nearest Airco office.

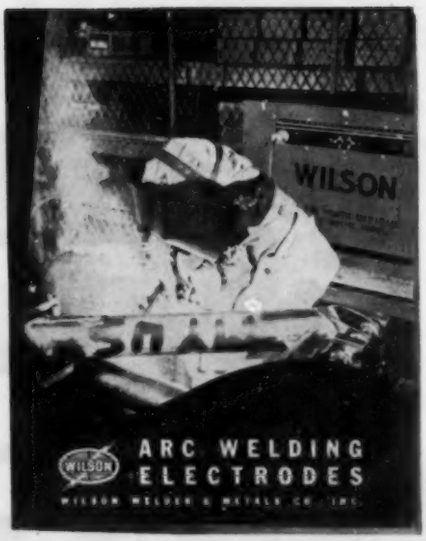
SELECTION OF ARC WELDING ELECTRODES

Arc Welding Electrodes, a new 32-page illustrated catalog published by Wilson Welder & Metals Co., Inc., is designed to guide electrode users in the selection of the right electrodes for any specific job.

This catalog supplies complete data on the proper electrodes to be used for all types of work on a wide variety of base metals, and describes the approved welding procedures for each application.

Electrodes are recommended for use on mild steel, alloy steels, low-alloy high-tensile steel and stainless steels. Additional sections are devoted to electrodes designed for nonferrous metals such as aluminum bronze, aluminum, and manganese bronze.

Chemical analyses, specifications and other engineering data are supplied for each electrode.



Copies of this booklet may be obtained from Wilson Welder & Metals Co., 60 East 42nd St., New York 17, N. Y., or from the nearest Wilson distributor.

CHART ON ALLOY WELDING

A new and unusual reference chart on high- and low-alloy welding electrodes has just been announced by Arcos Corp. The data include tables on corrosion resistance, on heat resistance and on weld metal surfacing, as well as the chemistry of the weld metal. Welding current and voltage tables give information of value to the operator.

The chart is 20 x 30 in. for wall mounting. A copy will be sent upon request to Arcos Corp., 1515 Locust St., Philadelphia 2, Pa.

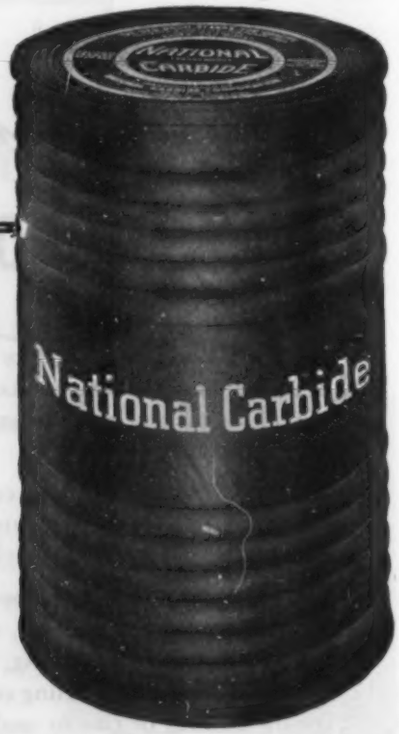
WELDING MANUAL

Published by The Quasi-Arc Company, Limited, Bilston, Staffordshire, England Price 3*s*. 6*d*.

This manual has been produced partly with the object of providing the novice with the fullest advice and instruction in all spheres of arc welding; partly for the welder who for one reason or another has had to concentrate on a narrow field of application and who now wishes still further to develop his practical ability and to widen his knowledge of welding, and partly as an aid to the welding shop supervisor and those engineers concerned with the design of welded fabrications.

The book consists of 168 pages copiously illustrated and is divided into five parts on Elementary Instruction Welding Mild Steel; Advance Instruction of Welding Mild Steel; Welding Materials Other Than Mild Steel; The Welding Shop—Welding Equipment; and The Drawing Office—Loads, Stresses and Procedures.

National
Carbide
IN THE RED DRUM
EFFICIENT
ECONOMICAL
DEPENDABLE

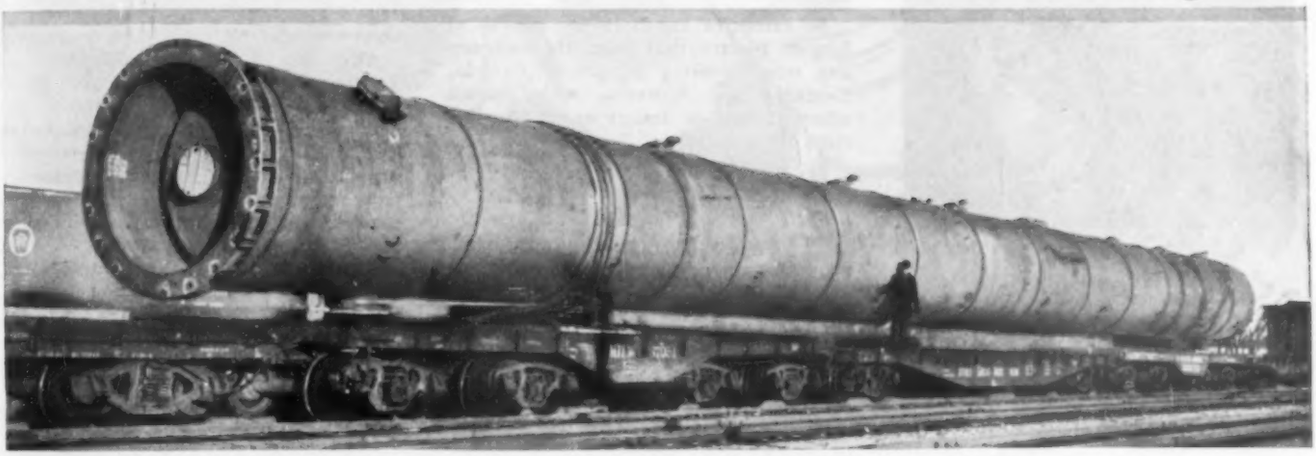


FOR WELDING and CUTTING
Use National Carbide in the Red Drum
Write us for information as to nearest available stock.
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York, N. Y.

1925

The first SMITHway pressure vessel established an electric arc-welded construction that overcame the most serious industrial hazards ever known in the petroleum industry.

In 1925, *the First* . . . In 1946, *the Largest*



1946

Twenty-one more years of unending welding research, makes possible today this single-piece 160-foot 446,000-lb. deisobutanizing tower; a SMITHway vessel which produces 652,000 gallons per day of butane.

ACTUAL shop production has proved SMITHway Certified Welding Electrodes from the day they were first developed. A. O. Smith plants use more than 320,000 a day; millions more are used by other manufacturers.

This wealth of production and application experience has been paralleled by continuous welding research in A. O. Smith laboratories. Each year since 1917 has seen the development of improved SMITHway Electrodes. Each year has seen these electrodes employed by A. O. Smith to pioneer the welding of every type of steel product . . . small, simple products no less than structures weighing up to half a million pounds.

For detailed specifications of SMITHway Certified Electrodes and their application to specific welding jobs, send for the SMITHway Welding Guide.

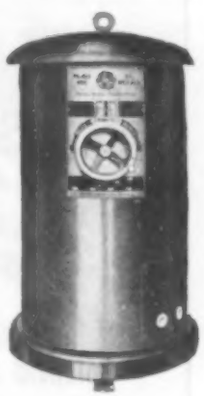
Mild Steel . . . High Tensile . . . Stainless Steel

WELDING ELECTRODES

made by welders . . . for welders

SMITHway A.C. Welders

Six models, including three new models of 150-, 200-, and 250-ampere capacity. Heavy Duty Models of 300-, 400-, and 500-ampere capacity. Write for complete specifications and prices.



SMITHway Certified WELDING ELECTRODES

A.O. SMITH Corporation

NEW YORK 17 • PITTSBURGH 19 • CHICAGO 4 • TULSA 3
HOUSTON 2 • DALLAS 1 • LOS ANGELES 14 • SEATTLE 1
INTERNATIONAL DIVISION: MILWAUKEE 1 • In Canada: JOHN INGLIS CO., LIMITED

FOUNDER OF LINCOLN ELECTRIC HONORED ON COMPANY'S FIFTIETH ANNIVERSARY

A silver plaque honoring John Cromwell Lincoln as founder of The Lincoln Electric Co., was presented him on Dec. 5th by the firm's employees as a token of their esteem to mark the company's fiftieth anniversary.

J. C. Lincoln

Lincoln started the concern with a capitol of about $150, just 50 years ago in downtown Cleveland.

Now Chairman of the Board and a resident of Phoenix, Ariz., for the past several years, J. C. Lincoln has seen his firm grow to its present position as today's largest producer of electric arc-welding equipment.

Under the leadership of his younger brother, J. F. Lincoln, president, this manufacturing concern has been widely publicized for its incentive system of worker-management relations, the affairs of which are today's prime topic in industry.

Since its inception, the company has pioneered in the improvement of welding machines and processes having developed many of the outstanding patents in the industry.

So extensive has been the growth of Lincoln Electric that today the company has manufacturing plants in Canada, England and Australia with branch offices, agents or dealers in all principal cities of the world.

NEW CHART LIST WELDING ELECTRODE PROPERTIES

Here's a chart that will prove to be very valuable in the welding shop as well as in the office of the welding engineer. It's a reference chart that gives the chemical and physical properties of all of the Page Welding Electrodes and Gas Welding Rods.

The chart should prove to be important also to the welding superintendent, the general engineer, the metallurgist and the purchasing agent.

A tremendous amount of welding data is clearly condensed and arranged for easy fact-finding. The chart is large, 17 × 25½ in., for hanging but it will easily fold down for filing away in a desk drawer.

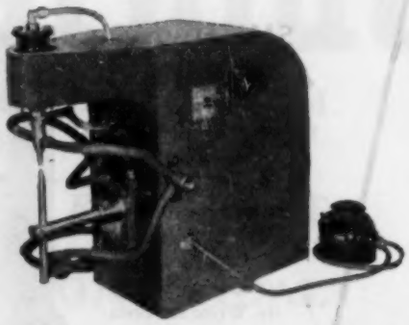
When writing to Page Steel & Wire Division, American Chain & Cable Company, Inc., Bridgeport 2, Connecticut, please refer to Wall Chart DH-1314.

GAS HOLDERS

A 50-page bulletin (W-45) giving a comprehensive picture of the design and construction of wet seal gas holders has just been published by the Stacey Bros. Gas Construction Co., Cincinnati 16, Ohio, one of the Dresser Industries, and is available on request. Valuable engineering data on welding technique, pressure, painting surface, corrosion and general dimensions of all sizes of gas holders up to 10,000,000 cu. ft. are discussed.

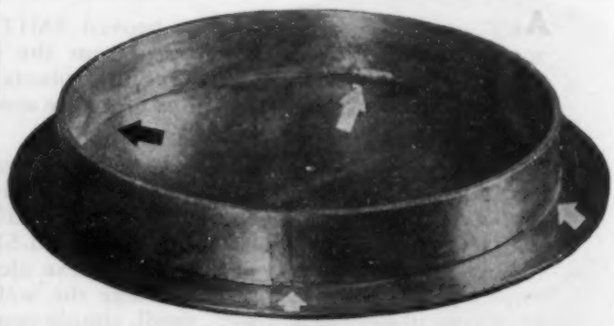
Numerous cross sections through the gas holder are shown, including information and tables on the operation and care of wet seal holders. This bulletin details the construction methods starting from the laying of the bottom to installing the tank shell, holder sections and guide frame.

3 K. V. A. • 220 Volts • 60 Cycle
Single Phase • Air Operated
Bench Type • No. 263-A



Solenoid Air-Valve Foot-Switch Operated
Built-in Electronic Timer
Adjustable Pressure Switch

WELDEX INCORPORATED
7336 McDonald Ave., Detroit 10, Mich.



GET THE FACTS ON ALUMINUM BRAZING

Nothing tricky about Aluminum when you use the KRE-CO ALUMINUM BRAZING PROCESS. Our simple yet effective method is being used successfully—saving time and money—doing a better job of bonding. Bulletin J 2 gives the facts. Yours upon request—it belongs in your files.

KRE-CO MULTICHEMIC FLUX
DIVISION OF
CHARLES W. KRIEG CO.
52-60 Dickerson St. Newark 4, N.J.

How Murex Type MA Helped Us out of a Jam

We'd almost gotten our new arc welding department running perfectly, when in comes this special carbon-moly steel pipe job that threatened to knock us back on our heels.

I went over the situation with Tom, our arc welding super. and he was not happy about it.

"The work can't be positioned," he said, "and we have to use these A.C. Machines—the D.C. sets won't be ready for weeks. On top of that, they want a tensile strength of 70,000 or more, with better than 22% ductility. That's going to take quite a rod."

"Right, Boss," I agreed. "*And Murex Type MA is the rod.* It was designed for *all-position* welding of carbon molybdenum and other high strength steels. It works on A.C. or D.C. It's especially useful for high-quality overhead and vertical welds. This rod was the first of its type in the industry...only been available for a couple of months. Want to try it?"

"You bet, Tom told me. "We'd better check on it right away."

We did, and it worked fine. We got the pipe job out on time, and now we stock a supply of Murex Type MA rods regularly for similar jobs. Tom swears by this new E-7011 electrode; the welders like it; and Quality Control thinks the work we turn out with it is swell. Of course, I'm happy, too.

METAL & THERMIT CORPORATION

120 BROADWAY, NEW YORK 5, N. Y.

ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

MUREX *Electrodes*

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

OXWELD-UNIONMELT CM-37 MACHINE CARRIAGE

A new-heavy-duty, straight-line machine, known as the Oxweld-Unionmelt CM-37 machine carriage has been developed by The Linde Air Products Co., Unit of Union Carbide and Carbon Corp. It can be used for carrying Unionmelt electric welding equipment, the CMA-21-B attachment for plate-edge preparation, single- or multiple-blowpipe setups for straight-line cutting, flame-hardening equipment, and the Oxweld C-45 blowpipe for cutting extra-heavy sections.

The use of high-strength aluminum alloys in the construction of the machine provide it with an ideal strength-weight ratio. Its weight as sold, without equipment (see illustration), is 87 lb.; thus it can be moved readily from job to job. Its over-all dimensions are 32 in. long, $12^1/_2$ in. wide and 9 in. high, plus $2^7/_8$ in. for the forward-reverse lever. The standard machine is equipped with a 110-v. a.-c. unidirectional motor of $^1/_4$ rated electrical horsepower. Reversing is accomplished mechanically through gears. Machines are supplied with speed ranges of 2 to 50 in. per minute for general industrial use; and 7 to 210 in. per minute for use with the Unionmelt welding process. An electric speedometer is located in the machine cover so as to be within easy view of the operator at all times. There are two calibrations—one for operation on track and one for operation directly on the workpiece.

The Oxweld-Unionmelt CM-37 Machine Carriage Shown Here as Sold—Without Equipment

The CM-37 will operate on CM-21 track or, where accuracy of travel is not important it can be operated on a standard 10-in., 25.4-lb. I-beam. It also can be operated directly on the steel plate or other flat workpiece, if desired. With the addition of accessory equipment for plate-edge preparation, flame-hardening, heavy cutting and other applications, this machine offers the advantages of great flexibility and adaptability.

TWO NEW WELD-SPATTER-RESISTANT COMPOUNDS

Two new weld-spatter-resistant compounds, No. 9951 and No. 9952, have been announced by the Electric Welding Division of the General Electric Co. Both of the new compounds are specially formulated for use in the welding field wherever weld spatter is undesirable and must be avoided easily and economically.

Furnished in powder form, ready to be mixed with water, the compounds are identical in performance. The only difference between them is that the No. 9951 is nonadherent and can be readily removed with an air hose or a dry cloth, while the No. 9952 is semiadherent but can be quickly and easily removed with a damp cloth or a direct stream of water.

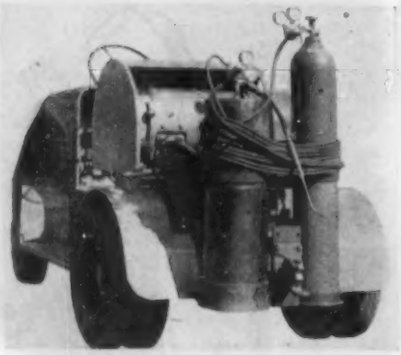
A feature of these compounds is that the surface of the work, even if slightly oily, does not require wetting before they can be applied. Another feature is that a special ingredient in the compounds eliminates the necessity of a water-soluble binder in order to obtain adhesion. Therefore, since the compounds are inert and cannot burn, they are completely smokeless

Available from distributors, the compounds are easily mixed and applied. Water is added slowly until a thin paste is obtained. No lumping occurs, and the mixture can be applied with an ordinary bristle brush. The brush can be safely left in the compounds afterwards or readily cleaned with cold water.

These new compounds are economical to use, since 1 gal. of either will adequately cover 450 to 750 sq. ft. of work, depending upon the thickness with which the compound is applied.

MOBILE WELDING UNIT

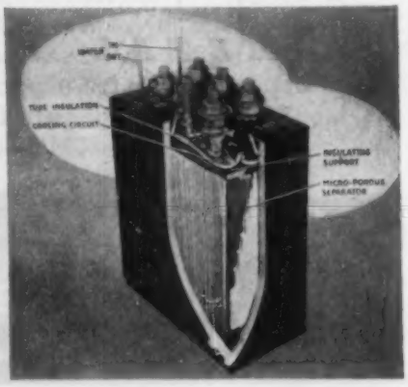
Able to maneuver close up to the work the Shop Mule reduces field welding to an operation almost as simple as shop welding. Carrying a P & H arc-welding generator and oxyacetylene equipment, the Shop Mule, manufactured by the W. F. Hebard Co., Chicago, is a completely self-contained welding service unit for railroad and industrial use.



The P&H welding generator, with a capacity from 30 to 375 amp., is mounted under a roll hood behind the driver's seat and is followed by racks for oxyacetylene tanks. This convenient grouping saves operator's time and provides faster welding.

BATTERY-POWERED WELDERS

Announcement has been made by the Progressive Welder Co., 3050 East Outer Drive, Detroit, Mich., that its line of battery-powered resistance welders is now available with internally water-cooled storage batteries. The new Exide batteries developed exclusively for Progressive by Electric Storage Battery Co. of Philadelphia, Pa., have an effective capacity several times that of conventional storage batteries when used in this service. Chief reason for this is the high charge and discharge rates permissible with the cooled batteries. This in turn makes possible increased output with fewer batteries, especially when welding aluminum and other metals or alloys requiring high fusion currents. Other advantages are decreased battery maintenance, longer battery life, more constant operating temperature, reduction of evaporation and refilling required, etc.



THE CHAMPION

RIVET COMPANY

CLEVELAND, OHIO — EAST CHICAGO, IND.

These battery-powered welders are particularly suitable for use in localities where electrical power facilities are not sufficient to handle the high demands imposed by conventional resistance-welding equipment. However, even where power facilities are available, the lower plant investment and lower maintenance and operating costs associated with storage battery welders often result in a sizable reduction in the unit cost of welded products.

Water-cooled batteries specially developed by "Exide" for Progressive Welder Co. new line of storage-battery powered resistance welders, are said to multiply capacity and greatly reduce gassing. Maintenance is reduced, life is increased, workers' health protected.

ELECTRONIC CONTROL WIDENS SCOPE OF OXYACETYLENE CUTTING MACHINES

A new "electric eye" tracing device for pantograph type oxyacetylene cutting machines that radically simplifies steel cutting operations and for the first time makes intricate design cutting practical—considerably expanding the present application of torch cutting machines in industry—has been announced by Air Reduction, 60 E. 42nd St., New York 17, N. Y. The new device, applied to machine gas cutting in collaboration with General Electric Co., will be known as the "Electronic Bloodhound." It completely eliminates expensive metal and wood templates and all other mechanical or manual auxiliary guiding devices.

Electronically controlled tracing equipment cuts the most complicated shapes with great precision from quickly prepared outline drawings or silhouettes of the desired piece. There are no limitations to the variety of designs which may be cut as the electronic tracing head faithfully follows the most complex angles and curves with extreme accuracy.

A new field of application has been opened in machine production cutting through the "chain" method of reproduction made possible with this type of template. In this chain method, a series of identical shapes are drawn on the template and connected with a continuous line, making production cutting of several pieces possible in a single operation.

In plants where a great variety of special shape cut pieces are made, the economy of this low-cost template preparation is particularly important. Improved cuts of consistently uniform quality—the economy and reduced scrap with electronic torch control equipment may be realized in standard production cutting as well as in shops where requirements call for a great variety of special shape cut pieces. Alterations may be quickly made—a fact of particular importance when small dimensional changes are made in a part. Where cutting machines are used for plant maintenance work, jigs and fixtures may now be economically shape cut with comparatively little effort.

Cuts Such as These Show the Ability of Electronic Tracing Equipment to Follow Any Angle, Contour or Corner with Great Accuracy

Shape cutting is no longer limited to the ability of the tracing device to follow template contour and sharp corners may be cut without subsequent machining or the use of elaborate jigs. Shapes are now cut directly from a drawing with exacting precision—whether the order calls for 1 or 1000 pieces. Human error and previous mechanical restrictions have been eliminated.

Templates required for electronically controlled cutting are simple outline drawings or silhouettes—a black outline about $^1/_8$ in. wide against a white background or any other color combination which provides sufficient light contrast. These drawings may be treated with a protective coating for long life.

Electronic Tracing Equipment consists of two units—the tracing head and con-

...is THIS your cleaning problem?

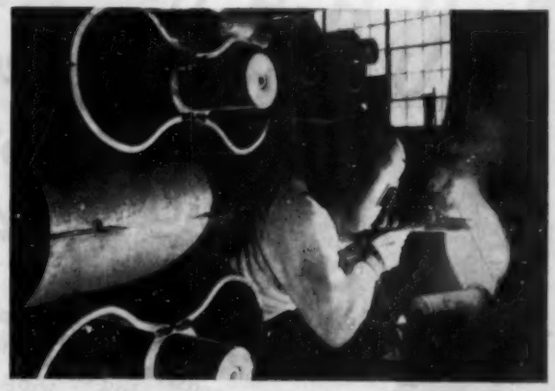
Preparing Aluminum Surfaces for Spot Welding

Are you interested in successful shop-tested practices for properly preparing aluminum prior to spot welding? Do you want timely information that will help you to handle preparation work faster, more effectively than ever before? Then send for a copy of the Oakite Surface Preparation Manual.

The data contained in this specially-prepared Manual will enable you to obtain more welds . . . better welds in less time. Details of the necessary equipment are augmented by informative diagrams. Your FREE copy will be gladly sent on request.

OAKITE PRODUCTS, INC., 18E Thames St., NEW YORK 6, N. Y.
Technical Service Representatives Conveniently Located in All Principal Cities of the United States and Canada

OAKITE Specialized CLEANING
MATERIALS · METHODS · SERVICE · FOR EVERY CLEANING REQUIREMENT



FOR 32 YEARS UNITED HAS BEEN LICKING ALMOST IMPOSSIBLE WELDING PROBLEMS

In war and in peace, United engineers and craftsmen have taken pride in their ability to produce large, rangy or complicated weldments.

Lessons learned in wartime techniques can now be applied to your weldments.

Our engineers can serve you best by studying your drawings to determine if your product will improve through fabrication. Perhaps welding will lighten it—increase its strength—lower costs.

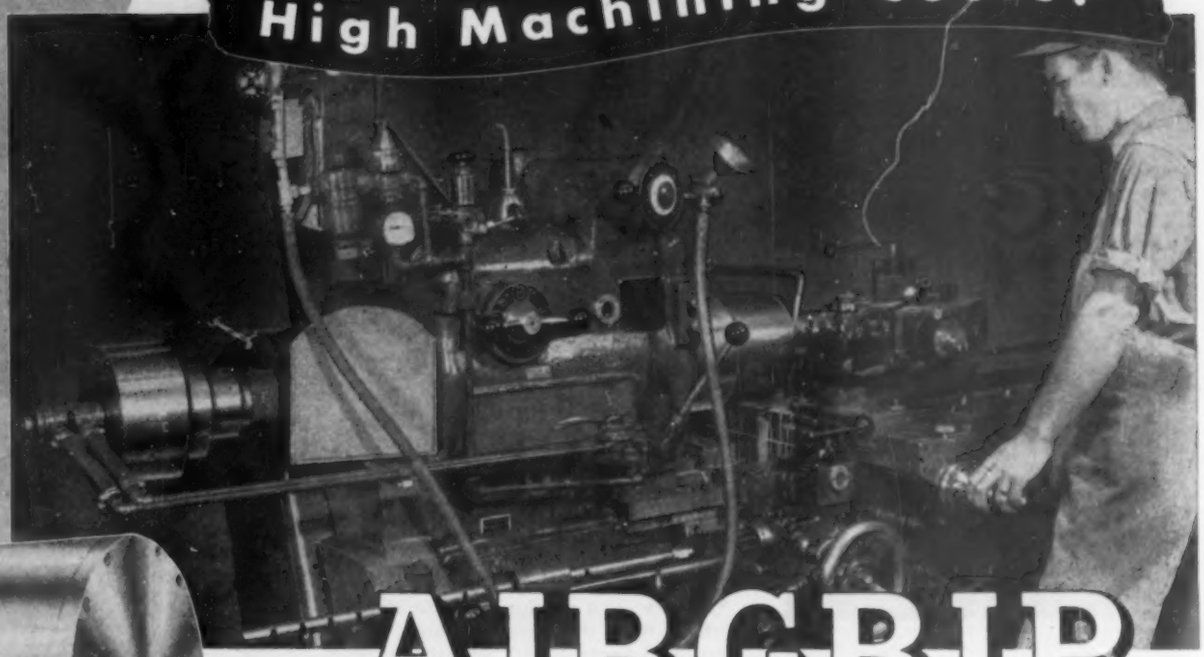
No obligation, just write.

WELDING ENGINEERS · UNITED CO. · MIDDLETOWN, OHIO · SINCE 1913

THE UNITED WELDING CO.
MIDDLETOWN, OHIO
WELDING FABRICATORS OF MODERN DESIGNS

An Important Step in Reconversion!

TURN DOWN High Machining Costs!



AIRGRIP

REVOLVING Air Cylinders

Cost Cutter No. 1

Meet the coming demand for production "at a price" instead of production "at any price"!

"AIRGRIP" Cylinders cut costs by big time savings. Patented double ball bearings permit speeds formerly impossible. Can run for years without attention. Wear automatically taken up by air pressure. No manual adjustments.

"AIRGRIP" Chucks

Cost Cutter No. 2

Step up machine output with "AIRGRIP" Chucks. *Two-fisted* gripping power—air locking power plus a 2-way cam-wedge locking power which locks jaws mechanically when gripping either externally or internally. Even if air supply fails, cam-wedge locking power holds work securely.

"AIRGRIP" Non-Rotating Cylinders

Cost Cutter No. 3

For pulling . . . pushing . . . lifting . . . controlled, safe, smooth, dependable power! Heavier walls—9/16"—require *no tie-rods*—means either end of cylinder removable, leaving rest completely assembled . . . no distortion of rods . . . streamlined appearance . . . less over-all space . . . easy to make repairs. Piston packings are graphite treated.

OTHER ANKER-HOLTH COST REDUCERS—Air-operated Collets, Arbors, Mandrels, Drill Press Chucks, 2- and 3-jaw Finger and Compensating Chucks, Lubricating Assemblies, 3- or 4-way Air Valves (hand or foot operated), etc. Also Hydraulic Power Units and Fittings.

Hydraulic as well as air-operated Chucks and Cylinders, (Rotating and Non-Rotating)

Representatives in all principal cities

Write, mentioning products on which you desire bulletins

ANKER-HOLTH MFG. COMPANY

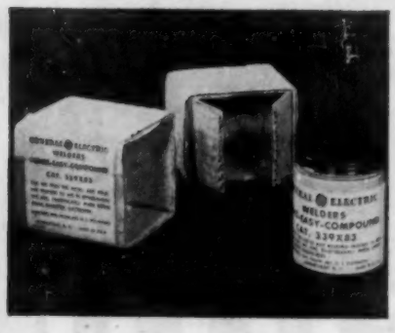
2798 Connors Street Port Huron, Michigan

When buying new lathes, specify "AIRGRIP" Chucks and Cylinders.

trol box. All working parts are fully protected and the electronic tubes designed for long life. This equipment is easily attached to any Oxygraph or Travograph cutting machine in place of conventional equipment.

NEW ARC-WELDING AID

A new arc-welding compound designed to aid in instantaneously creating and maintaining a metallic welding arc where low currents and small-diameter electrodes are employed has been announced by the Electric Welding Division of the General Electric Co. Known as Strike-easy, this new compound is easily applied and can be used on any kind of metal with any type of electrode.



The compound, which is in paste form, is available from distributors in 1-lb. glass jars, completely ready for use. No mixing or other preparation is required.

SOFT SOLDERING FLUX

A new organic soft solder flux which is described as more effective than common rosin fluxes and which does not normally leave a corrosive residue on the work, is announced by Superior Flux Co., Public Square Bldg., Cleveland 13, Ohio. This is known as "Superior No. 30 Supersafe Soft Solder Liquid Flux."

Because of its activity in effecting the wetting of the joining surfaces, this flux, in many cases, contributes to easier soft soldering of metal combinations which have been considered difficult to solder.

Another advantage in many soldering operations, as on electrical and radio equipment, is the complete absence of injurious deposit at the joint. The effective acid action of the flux as it comes from the container is completely neutralized at ordinary soldering temperatures, when properly used, leaving a residue that is normally noncorrosive, nonconductive to electricity, nonhygroscopic and easily soluble in water.

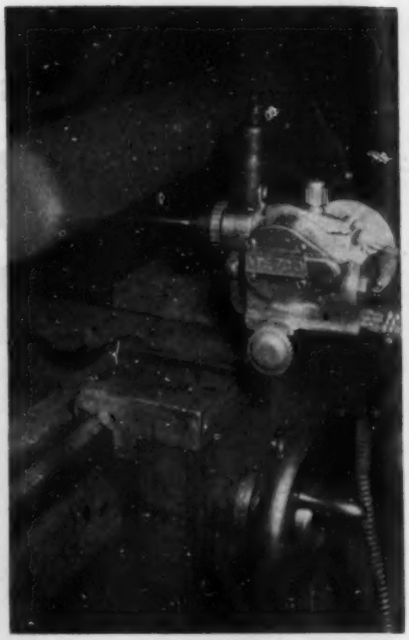
The composition of the new flux was developed by Battelle Memorial Institute in an investigation sponsored by the Tin Research Institute. So far, it has been largely used in war industries. Its manufacture by Superior Flux Co. will help make it available for a wide variety of industrial soldering where permanent freedom from flux residue corrosion must be assured.

METALLIZING GUN

The new Metco Type Y Metallizing Gun, unlike the hand gun, is designed and built specifically for mechanical mounting and continuous operation. Its many outstanding features include the use of $^3/_{16}$-in. wire, a revolutionary "first time" which, when combined with an acetylene pressure of only 15 psi., more than doubles any previous spraying speeds.

The Metco Type Y Gun—because it is designed with a total disregard to weight and size limitations necessary for the hand gun—is much heavier and much more rugged in construction. Gears, worms and bearings, several times larger than any used previously, virtually eliminate wear and replacement. This coupled with lower operating and maintenance costs effects considerable savings.

Another revolutionary improvement, "Fluid Lubrication" and a built-in forced-feed pump which has no parts to wear, assures an adequate supply of lubricant to all bearings regardless of operation position. The gun is nonsensitive to gas and oxygen pressure variations as much as 10 lb. either while lighting or while spraying.



These and other features are described in great detail in Bulletin 49P which will be mailed on request. Metallizing Engineering Co., Inc., 38-14 30th St. Long Island City 1, N. Y.

BOUND VOLUME JOURNAL

The AMERICAN WELDING SOCIETY has made arrangements for members who wish to have their Journals for 1945 bound in attractive, black cloth covers, to do so by sending copies of the twelve issues to Russell-Rutter Company, Thirty-Third Street and Eighth Avenue, New York, N. Y., Att. Mr. Russell Lauben, Jr. A special reduced rate has been arranged at $2.75 per volume providing the issues of the JOURNAL are sent to the binder on or before February 15, 1946. Journals received after this date cannot be bound at this reduced rate. The bill for the binding and return postage will be sent direct from the Society's office.

NEW LOW TEMPERATURE ELECTRODES

EutecTrode 28

A Coated Electrode for the Metallic Arc Welding of Bronze, Brass, Copper

For reduced production costs—can be used with AC and DC — deposits sound welds with good corrosion resistance — a close color match to red bronzes and yellow brasses—tensile strength 45,000 psi.

Bronze Castings welded with EutecTrode 28. This is the first electrode developed that can successfully weld copper, brass and bronze with an AC-DC metallic arc. Completely machinable, perfect color match, high tensile strength.

Take advantage of these improved EutecTrodes:

24—for cast iron—no preheat—AC-DC
24B—for cast iron—AC-DC
30—for copper—AC-DC
2100—for aluminum alloys—DC

and these EuteChroms:

2—for hard overlays on worn parts — AC-DC
4—for work-hardening overlays—AC-DC
6—for overlays on tool steel—AC-DC
8—for high hardness, impact strength — AC-DC
12—for extremely hard overlays—AC-DC

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typical of Federal resistance welding production equipment available to every type of metal working industry. If you have a metal fabrication, fastening or closure problem it is important for you to know everything possible about spot, flash, seam, lap-butt, roll-spot, projection and percussion welding with automatic equipment. The name of authority in this field is

Federal

Ask for Barrel Welder Book SP 245—or All Products Bulletin SP 345.

AND WELDER COMPANY

206 DANA STREET
WARREN, OHIO

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 10¢ from the Commissioner of Patents, Washington 25, D. C.

2,387,715—Welding Materials and Processes; Charles A. Cadwell, Cleveland Hts., Ohio, *Inventor*. Assigned to The Electric Railway Improvement Co. *26 claims*.

The patent relates to the production of metal having a lower melting point than iron. The metal is produced by an exothermic reaction between an oxide of such metal and aluminum where sufficient metallic iron is present in the reaction mixture to reduce a substantial part of the oxide of such metal.

2,387,864—Starting Device for Gravity Arc Welders; Joseph M. Tyrner, New York, N.Y., *Inventor*. Assigned to Air Reduction Co., Inc. *5 claims*.

In the gravity-feed arc-welding apparatus shown, the frame includes a slide part and means for supporting the slide part inclined to the work piece. An electrode holder is slidable down the slide part and it carries an electrode which extends into engagement with the work piece to rest thereon. The actual arc starting device includes manually operable means extending between the frame and the holder and adapted to lift the holder and electrode on the slide piece so as to draw an arc from the workpiece.

2,387,888—Electrode Holder; Thomas S. Donnelly Jr., Detroit, Mich. *Inventor*. Assigned to Bordon Mfg. Co., Inc. *5 claims*.

This electrode holder includes a supporting prong having a pair of spaced apart lugs projecting therefrom, and an electrode engaging jaw on the prong. A cooperating clamping jaw is mounted on a pivot member supported on the lugs so as to be in pivotal relation to the first mentioned jaw. The outer faces of the lugs are insulated and the insulating material is secured in position by means which also secure the pivot member in operative position relatively to the lugs.

2,387,889—Welding System; Leo O. Dorfman, Forest Hills, Pa., *Inventor*. Assigned to Westinghouse Electric Corp. *12 claims*.

The patent relates to safety control means for an arc welding system wherein an arc welding transformer has a secondary winding for connection to an arc welding circuit. A reactor is connected in shunt relation with the secondary winding to reduce the open circuit voltage, and it is saturable at a voltage intermediate the arc voltage and the reduced open circuit voltage. Switch means are connected in series with the primary of the transformer and a thermal device, responsive to temperature conditions of the reactor, is provided to effect operation of the switch means to disconnect the primary of the transformer from its power source.

2,387,905—Welding Electrode; Joseph Hoch, Congress Park, Ill., *Inventor*. Assigned to Witlek Mfg. Co., *6 claims*.

This patent covers a spot welding electrode which has a slotted work-engaging end divided into a plurality of spaced flat spot welding contact faces. A pilot is mounted in, and electrically insulated from the electrode and it extends through the slotted portion of the electrode outwardly beyond the contact faces.

2,388,090—Electrode Assembly; Edwin W. Scott, Scotia, N. Y., *Inventor*. Assigned to General Electric Co. *6 claims*.

An electrode assembly for an electric discharge device including an elongated electrode, which has a resistance that is relatively high with respect to the remainder of the circuit in which it is connected, is shown in this patent. A first conductor supports and supplies current to the electrode and it includes a portion that encircles and tightly grips one end of the electrode. Such portion of the conductor is provided with a section for supporting the electrode from a lead-in conductor of the electric discharge device. A second conductor is present and it has one end secured in an opening formed in the electrode and its other end is secured to said first conductor.

2,388,430—Method & Apparatus for Welding; George S. Mikhalapov, Media, Pa., *Inventor*. Assigned to The Taylor-Winfield Corp. *14 claims*.

This patent relates to electric resistance-welding apparatus of the electromagnetic storage type having an inductive reactor and a secondary welding circuit positioned in operative induction relation with respect to the reactor. The apparatus includes a circuit for applying direct current to the reactor and means for interrupting the current flow through the reactor. Means also are provided to control the rate of rise of the welding current in the secondary circuit and it comprises a capacitance in parallel with the reactor. A resistance is connected across the circuit-interrupting means to control the rate of decay of the current induced in the secondary circuit.

2,388,587—Cooling Means for Electrode Tips; Thomas A. Wilson, *Inventor;* Stratford, Conn. Assigned to United Aircraft Corp. *12 claims*.

The welding electrode covered in this patent includes an open ended tubular body and a hollow tip member having a closed and an open end with its open end removably connected to the open end of the tubular body. Means for circulating a cooling fluid stream within the body and the tip are provided and they comprise an axially disposed tube fixed to the body and terminating adjacent the open end thereof. Then a cooperating axially disposed tube is carried by the tip member and has one end terminating adjacent the tips closed end, while its other end telescopes with the tube in the body. Further means are provided to position the tube carried by the tip in its desired position during removal and insertion of the tip member in the body member.

2,388,754—Machine for Welding; Frank Martindell, Western Springs, Ill., *Inventor*. Assigned to Western Electric Co., Inc. *8 claims*.

This patent relates to a machine for electrically welding a piece of contact metal to a switch spring and it has means for clamping an end portion of a continuous strip of contact metal to a switch spring. The machine also has means for serving the clamped end portion from the strip and means for retracting the continuous strip from the severed portion.

2,388,811—Welders' Comporting & Accessory Suspension Belt; Michael Zatko, Oaklawn, Ill., *Inventor*. *1 claim*.

A special type of workman's belt is disclosed in this patent and it has rings and other means thereon for supporting articles to be carried by the worker.

2,389,034—Welding Machine; Charles Eisler, Jr., Maplewood, N.J., *Inventor*. Assigned to Eisler Engineering Co. *2 claims*.

The welding machine shown has a support with a slide bearing secured thereto, the slide bearing having a flanged ram positioned therein. Means are provided to clamp the bearing on the ram, while a turret holder, having a boss thereon, is secured to the flange on the ram by suitable means. The turret has a recessed portion for complementary engagement with the boss of the turret holder to position the turret rotatably thereon. A circular slot of "T" shape in cross section is made in the turret, a gate of "T" shape cross section communicates with the slot, and bolts are positioned in the slot through the gate therefor with the heads of the bolts engaging the slot to suspend the turret on the bolts. Of course, apertures for the bolts are formed in the turret holder and ram while also, a welding member is secured to the turret. Suitable devices engage the bolts and ram flange to lock the parts together when tightened and to enable the turret to be rotated on the bolts when such devices are loosened.

2,389,324—Spot Welding Machine; Arthur Pedley, Bentley near Walsall, England, *Inventor*. Assigned to Rubery Owen & Co., Ltd., *5 claims*.

A multiple spot-welding machine is disclosed, which machine has a plurality of movable electrodes and a block to receive the electrodes. A rigid current-conducting bar is secured to the block, while spaced plungers are carried by the block and coact with one of the electrodes. Then spring means are provided to urge the plungers to press the one electrode they coact with into contact with one side of its associated bore so as to ensure good conductivity between the bar and that electrode.

2,389,559—Electrode Holder; Frank R. Smith, Los Angeles, Cal., *Inventor*. *11 claims*.

The electrode holder of the patent includes a base member and a pivoted lever

FOR SUCCESSFUL ALL-POSITION A.C. WELDING OF HIGH TENSILE-STEELS

USE THESE HIGH-QUALITY HEAVILY-COATED RACO ELECTRODES

RACO 7011 for carbon-molybdenum steel piping, structural silicon steels and similar steels with 55,000 psi yield point.

RACO 8011 for lower carbon grades of low-alloy structural steels —such as Man-Ten and N-A-X High-Tensile.

RACO 9011 for medium carbon steels and for steels with low alloy content such as A.S.T.M.—A212.

RACO 10011 for high-tensile steels in the vicinity of 100,000 psi, such as 2½% and 3½% nickel steels, SAE 6120, SAE 4340 and 0.50% carbon steel.

These new low-alloy steel electrodes conform to Specification A233-45 T of the American Welding Society as follows:

A.W.S.—A.S.T.M. Classification	Reid-Avery Grade	Min. Tensile Strength of Deposited Metal (stress relieved)
E-7011	Raco 7011	70,000 psi
E-8011	Raco 8011	80,000 psi
E-9011	Raco 9011	90,000 psi
E-10011	Raco 10011	100,000 psi

These electrodes are designed for all-position welding with alternating current. Direct current reversed polarity also may be used with equal success. The electrodes are available in sizes from 3/32" to 5/16".

Our twenty-five years experience in the application of skilled craftsmanship to highest quality materials is your guarantee of highest quality product.

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Since 1919 Producers of ARC Welding Electrodes and Welding Rods

member which have hook and pin pivotal connecting means with the hook carrying member being slidable lengthwise to effect engagement or disengagement of the hook with the pin. The members have welding rod gripping jaws, while means are provided to insure engagement of the pivotal connceting means between the members.

2,389,569—ELECTRODE HOLDER; Henry J. Wagner, Jackson, Mo., *Inventor. 3 claims.*

A special type of holder, including upper and lower tong members that have jaws formed thereon for engaging an electrode, is disclosed. One tong member has an upwardly projecting ear extending from its rear portion and this ear is entirely enclosed in the flexible insulating handle provided. The position of the upper jaw can be controlled by the ear and means are provided to urge it upwardly to force the upper jaw towards the lower jaw and normally maintain it in contact therewith.

Employment Service Bulletin

SERVICES AVAILABLE

A-511. Metallurgical Engineer desires position. Age 28, single. Willing to travel. Investigation of customer complaints on alloy steels; Metallurgical Instructor; Testing Laboratory experience; Metallurgist, Steel Company.

POSITIONS VACANT

V-182. Assistant Research Metallurgist: One or two men for welding research with old established company Boston district, must be well groomed in the fundamentals of metallurgy and electricity. State age, qualifications and experience. Salary will be commensurate with qualifications and experience.

V-183. Salesman wanted. Arc Welding Apparatus supplies. Prefer man with some mechanical school training. Salary and commissions. Excellent territory.

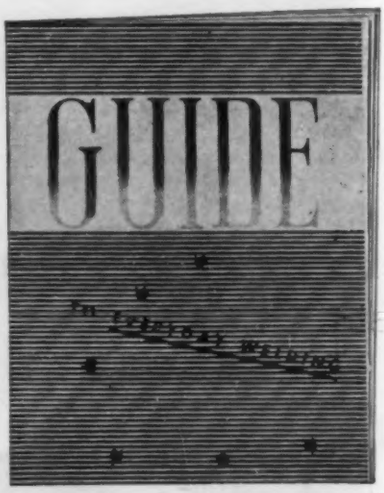
Welding Engineers wanted. Civil Service Rating 1, 2, 3, 4, and 5. Also a Metallurgist of Civil Service P-4 caliber. Engineers with good educational background preferred. Experience in Laboratory procedures. For further information write, phone or wire: Personnel Officer, U. S. Naval Engineering Experiment Station, Annapolis, Maryland, and request interview for Engineering position in the Welding Laboratory.

GUIDE TO EVERYDAY WELDING

Page Steel & Wire Division of American Chain & Cable Company, Inc., Monessen, Pa. recently issued a new 8-page booklet titled "Guide to Everyday Welding."

The information is arranged in easy-to-find tabular form, indexed by industries, listing types of jobs and equipment on which welding is used, showing character of welds and types of electrodes or gas welding rods for each application.

A condensed chart is included which shows the physical properties, correct recommendations and analysis of weld metal deposit for stainless steel, carbon steel, shielded arc and bare and sub-coated electrodes and gas welding wires. Copies of the booklet can be obtained on request.



CHIEF WELDING ENGINEER

Wanted immediately for large manufacturer of aircraft power plants. Position involves research and development as well as guidance in establishing and controlling production joining processes, including automatic and hand arc welding, spot and seam welding, brazing, silver soldering, etc., applied to heat and corrosion resistant alloys, alloy steels and aluminum alloys.

GRADUATE ENGINEER PREFERRED

Location—Eastern United States

Give complete details of education, experience, references and recent earnings.

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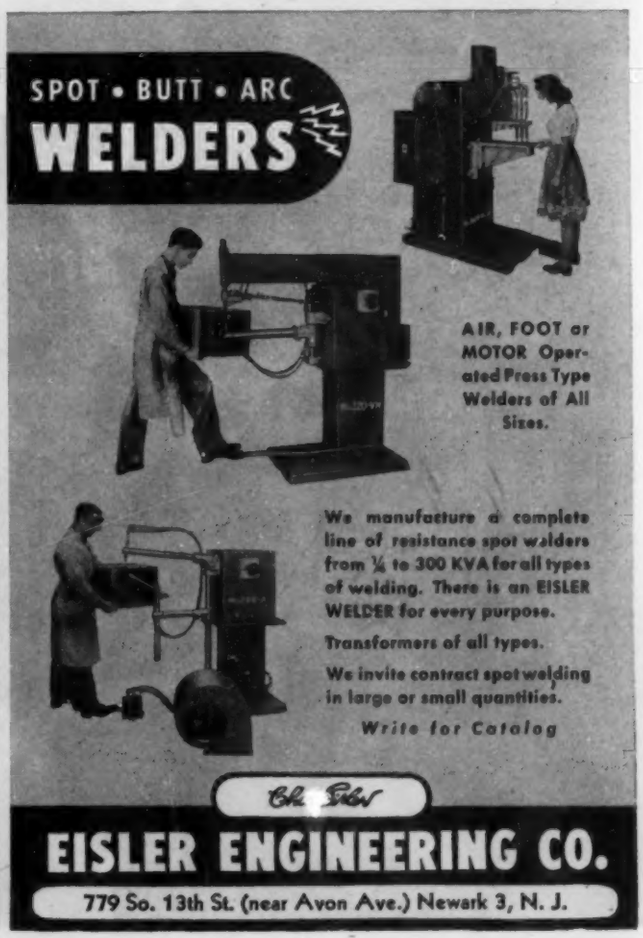
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WELDERS
AIR, FOOT or MOTOR Operated Press Type Welders of All Sizes.
We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.
Transformers of all types.
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"Take Advice"... *he says*

LOOK, SIR, at the advice given by many users of arc welding:

On heavy work, all positions, TRY "FLEETWELD 47" FOR EASE and get up to 40% faster welding

HOW TO USE "47". Intended for A.C. or D.C. . . . all positions. Take, for example, vertical fillet welds in heavy plate:

Weld vertically upward. Use single pass weave shown. Electrode sizes including 1/4" can be used. Do not remove arc from molten pool while making weld. Keep molten pool tilted up into the corner so the slag runs into outer edge.

RESULTS: Ability to use large size rods increases speed up to 40% over other all-position electrodes requiring smaller sizes.

Spatter is negligible. Simply tap the plate and the slag falls off.

FREE. *Handy, pocket-size "Weldirectory" gives procedures for eight types of "Fleetweld" and other Lincoln Electrodes. Ask for Bul. 437.*

THE LINCOLN ELECTRIC COMPANY
Dept. P-1 Cleveland 1, Ohio

GOOD ADVICE VIA MOVIES

The new Lincoln sound-color movie, "The Prevention and Control of Distortion in Arc Welding" by Walt Disney Productions, explains simply and clearly the causes and cures of distortion. A valuable aid to designers and production men. Available free for showing to groups. Ask for Bul. 709.

America's greatest natural **recourse**

ARC WELDING

SECTION ACTIVITIES

CHICAGO

Resistance Welding Night was held on Friday, November 16th, at the People's Gas Light and Coke Co. Auditorium. Carl Otto, supervising process engineer of Douglas Aircraft, spoke on "Resistance Welding in Modern Industry" based upon his years of experience in this field.

Two movies were shown. "Down Where the North Begins"—Ecuador, with its high mountains, tropical jungles, and modern cities, was the locale of this excellent colored film. "Crocodile Thrills"—Crocodile hunting in the Florida Everglades, in Africa, and finally in Burma.

CINCINNATI

The regular monthly meeting of the Cincinnati Section was held on Tuesday, November 27th at the Engineers' Club.

T. B. Jefferson, Editor of *The Welding Engineer*, was the speaker. Mr. Jefferson's subject was "Welding in the Post-War World."

A sound picture entitled "The Prevention and Control of Distortion in Arc Welding" was shown through the courtesy of The Lincoln Electric Co.

The usual social hour, complete with Dutch Lunch and entertainment, was enjoyed by the 55 members and visitors present.

CLEVELAND

On Wednesday, November 14th, the Cleveland Section had for its monthly meeting Judge Julius M. Kovachy, who spoke on "Psychopaths—Who Are They?" Judge Kovachy's talk was the Coffee Talk, given after the dinner which was attended by some one hundred and fifty members.

The main speaker of the evening was G. Fitch Cady, who spoke on "Distortion in Welded Structures." The experience that Mr. Cady has received in his connection with Chicago Bridge & Iron Co. gave light to some of the many problems which various members of the group had in the past and are having at present. There was an attendance of approximately 300 at this meeting.

COLUMBUS

The December meeting held on the 14th at the Battelle Memorial Institute was addressed by Mr. Hanna of the Ohio Industrial Commission, who spoke on "Safe Practices in the Welding Industry." Demonstrations in handling of welding equipment were made by J. H. Parker of the National Cylinder Gas Co.

DETROIT

The Detroit Section, through its Vocational Guidance Committee, is undertaking to arouse the interest of more young men in the art and science of welding.

In order that the boards of education and the staff members of the several schools might have a better appreciation of welding in industry, a shop tour of the River Rouge plant of the Ford Motor Co. took place on November 29th. The tour was arranged with the consent of R. H. McCarroll, executive engineer of the Ford Motor Co., and through the kind effort of E. Gourley, Ford public relations director.

In spite of the fact that the Ford Motor Co. was shut down, the management had sufficient personnel on the job to show the several types of welding used by the company. As a matter of fact, the guests were better able to appreciate the processes shown because there were no other distracting influences.

At the completion of the tour a round-table discussion was held on the hopes and aspirations of the Detroit Section in regard to vocational training and the opinion was expressed by the members of the several boards of education that the Section could depend on their co-operation.

Accordingly then, a representative committee of members of the Detroit Section under the capable direction of Professor J. R. Stitt, formerly dean of the welding engineering school of Ohio State University, is preparing lesson sheets for the guidance of the vocational schools and we have promised to undertake the task of assisting the instructors selected to better present the subject of welding in these schools.

Friday, November 9th, was a gala day for the Detroit Section when a joint meeting with the Industrial Electrical Engineering Society and The American Institute of Electrical Engineers was held in the afternoon and evening at the Horace H. Rackham Educational Memorial. Between sessions, one hundred and four members and guests gathered for dinner at the Wardell-Sheraton Hotel.

The program consisted of a Resistance Welding Forum, under the capable direction of John D. Gordon. The following participated:

Afternoon Session: "Application of Capacitors to Flash Welders," J. F. Deffenbaugh, Federal Machine & Welder Co.; "Manufacture of Chain:" Technicolor Movie; "Design and Measurements of Condensor Discharge Welding Transformers," T. W. Dietz, Taylor Winfield Corp., and G. M. Stein, Westinghouse Electric Corp.; "A New High-Speed Control for Gun Welders," Frank Roby, Square D Co.

Evening Session: "Standard Types of Electronic Welding Control," E. H. Veder, Westinghouse Electric Corp.; "Off Standard Resistance Welding Control," G. W. Garman, General Electric Co.

The attendance was unusually large and the discussion ran into the late hours of the evening. The meeting will long be remembered for its high caliber and instructiveness.

E. H. Vedder and G. W. Garman presented their papers at the meeting of the Saginaw Valley Division held at the Hotel Frankenmuth on Thursday, November 8th.

INDIANA

The November meeting was held Friday the 23rd, jointly with The American Institute of Electrical Engineers at the Lincoln Hotel, Indianapolis.

L. W. Clark of the Detroit Edison Co. gave a talk on the subject "Good Practices for Installation of Resistance Welders."

LEHIGH VALLEY

The regular monthly meeting of the Lehigh Valley Section was held on Monday, November 5th, at the Hotel Bethlehem, Bethlehem, Pa.

After the dinner, Chairman Kenworthy introduced Lt. Col. J. H. Brubaker, who is in charge of the Easton Community Veterans Service Center. Col. Brubaker discussed the work of the Center and the problems of the returning veteran.

H. O. Hill, Technical Chairman of the evening, introduced the speaker, H. C. Boardman, research engineer for the Chicago Bridge and Iron Co. Dr. Boardman gave the Section reflections from his wide experience in welding research.

LOUISVILLE

A dinner meeting of the Louisville Section was held in the Jr. Ballroom of the Seelbach Hotel, on Tuesday, November 27th.

Coffee speaker was Harry McTigue, general manager, Radio Station WINN. Mr. McTigue spoke on "Close-Up Baseball Personalities."

The principal speaker was P. D. Scott, of the Welding Equipment & Supply Co., Detroit, who was present through the courtesy of the Allied Weld-Craft, Inc., of Indianapolis. Mr. Scott spoke on "Tool Maintenance and Die Repair."

MARYLAND

Dr. Gilbert Doan and Dr. Robert Stout of Lehigh University, spoke on "Weld-

Industry Endorses EUTECTIC Low Temperature WELDING RODS* and FLUXES

"THE MOST REMARKABLE DEVELOPMENT† SINCE THE INVENTION OF THE WELDING TORCH!"

Robert F. Miller - President of Pottstown Mfg. Co., Pottstown, Pa.

MANUFACTURER OF MACHINE PARTS AND ASSEMBLIES, INCLUDING TUBE BENDING AND WELDED SECTIONS

"We fabricated these aircraft ordnance parts with EutecRods 16 for steel (1300-1600°F.), No. 1800 for ferrous and non-ferrous metals (940-1120°F.), No. 190 for aluminum and alloys (950-1060°F.) and No. 1601 for alloy steel (1020-1250°F.). The use of these Low Temperature Welding Rods reduced our production costs materially. As many as 4000 pieces were produced with a No. 16 rod, and inexperienced girls were expertly welding tough and delicate parts after only a few hours of instruction from our welding specialist George Bauer. Because EUTECTIC Low Temperature Welding Rods can be applied with ease, we maintained a greater operating efficiency among our plant personnel."

INVESTIGATE EUTECTIC TODAY

In production, EUTECTIC Low Temperature Welding Rods* play a vital role. Because they can be successfully applied by beginners—because they can be used with extremely low heat and produce welds that are more machinable, show less stress and distortion and exhibit consistently high strength—EutecRods and EutecTrodes are a growing factor in major civilian production work and are *rapidly displacing fusion welding and brazing.*

All EUTECTIC Alloys are now available for civilian production. By means of 48 specially developed Rods and Fluxes you can employ the many revolutionary advantages of EUTECTIC *Low Temperature* Welding. Get the facts today! Call in your local EUTECTIC Field Engineer and learn how EUTECTIC can be made to serve you.

Write for Eutectic's Civilian Production Folder EW-20 Today!

FLASH

DO NOT FORGET TO VISIT THE *EUTECTIC* EXHIBITS.

1. National Metal Show, Cleveland, Ohio
   February 4th to 8th. Booth C-310
2. National Chemical Exposition, New York
   February 25th to March 2nd B-462-463-464

See actual welding demonstrations. Complete display of welded samples and panorama depicting EUTECTIC'S achievements in 1945.

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†WHAT IS EUTECTIC?

EUTECTIC Low Temperature Welding Rods are a new type of welding alloys, which—

- **Bond to base metals well below the base metal melting point**
- **Avoid the dangers of stress and distortion characteristic of fusion welding**
- **Form exceedingly strong bonds through surface alloying**

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Name.....

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ability of Steels" at the November 16th meeting of the Maryland Section. This talk helped to clarify some of the highly technical work done on weldability at Lehigh and R.P.I. which has been reported in the literature.

MILWAUKEE

Regular meeting was held on Friday, November 30th, at the Ambassador Hotel, Milwaukee. Dinner preceded the meeting. After-dinner topic was "Social Security—Today and Tomorrow."

The Welding Address was presented by Mr. William Boese, welding engineer of the Pullman-Standard Car Mfg. Co., Michigan City, Ind. Mr. Boese gave a talk on the technique and sequence of welding freight cars.

NEW YORK

The regular monthly meeting of the New York Section was held on Tuesday, November 13th, at the Engineering Societies Building. Dinner at the Engineers' Club preceded the meeting.

W. G. Theisinger of the Lukens Steel Co., presented an interesting address on "The Effect of Plate Widths on Fabrication Costs of Pressure Vessels."

NORTHWEST

Leslie F. McPhee of the Whiting Corporation, Harvey, Ill., was the guest speaker at the December 4th meeting held in the Men's Lounge, Coffman Memorial Union, U. of M. Mr. McPhee's subject was on "Welding as It Effects Design."

NORTHWESTERN PENNSYLVANIA

The Northwestern Pa. Section held its second meeting on Tuesday, November 6th, at the Elks Club in Titusville. The dinner preceding the meeting was attended by 53 members and guests.

Immediately following the dinner, Charles Palmet, who for three years was interned in the Philippines, gave an interesting account of his experiences.

The technical session was addressed by W. G. Theisinger of Lukens Steel Company, who spoke on "The Effect of Plate Widths on Fabrication Costs of Pressure Vessels."

OKLAHOMA CITY

The December meeting of the Oklahoma City Section was held on the 6th at the Biltmore Hotel. Mr. R. F. Wyer, Application Engineer, Welding Division, General Electric Co., spoke on the subject "Automatic Welding."

ROCHESTER

The regular monthly meeting for December was held on the 6th, preceded with a dinner at the Powers Hotel. Mr. Bela Ronay, of the U. S. Naval Engineering Experiment Station, spoke on "The Fundamentals of Welding Stresses." A movie, "Evolution of the Oil Industry," was shown by the Bureau of Mines. Discussion led by Joseph O'Rorke, Eastman Kodak Co., on "The Welding and Fabricating of Alloys" followed.

SAINT LOUIS

November meeting held on the 16th at the Engineers' Club was addressed by Wm. J. Poehlman, Chief Spectographer of the A. O. Smith Corp., Milwaukee. There were approximately ninety members and guests present to hear Mr. Poehlman's review of the development of the spectrograph and its research and industrial applications. Mr. Poehlman's program served as an excellent introduction to the broad field of spectroscopy and gave a clear insight on many specific problems related to inspection and control of metals fabrication and, in particular, welding.

SAN FRANCISCO

F. E. McAtee, chief welding engineer of the Chicago Bridge & Iron Co., spoke on "The Safety of Large Field-Welded Pressure Vessels" at the November 26th meeting of the San Francisco Section. Mr. McAtee's talk was illustrated with slides and models, and he discussed the development of spheres, spheroids and blimps, and their behavior under test and in service.

SYRACUSE

R. W. Emerson, of the Pittsburgh Piping & Equipment Co., addressed the November 14th meeting on "The Fabrication of Welded High-Pressure Piping." Mr. Emerson's talk covered the welding design and procedure used in fabrication of high-pressure piping systems which must meet U-69 and P-102 requirements of the A.S.M.E. Boiler Construction Codes.

TOLEDO

The November meeting of the Toledo Section held on the 13th at the Macomber Vocational High School, was addressed by O. E. Cullen, who spoke on "Bright Annealing Furnaces and Its Uses."

WASHINGTON

On November 20th the Washington Section was privileged to act as one of the sponsors for the appearance of Dr. Charles F. Kettering, President, General Motors Research Corp. This meeting was distinctly unusual in that nine technical societies cooperated in presenting Dr. Kettering.

A capacity audience, estimated to exceed 1200, attended the joint meeting at the U. S. Chamber of Commerce. The audience was limited only by the size of the auditorium.

Dr. Kettering discussed the general subject of the relation of research to industry. He drew upon his vast experience to build up the thesis that research, although it may not produce immediate financial return, is vital to the interests of industry in that it provides a background of the knowledge basically required for the development of new products and the improvement of old.

The Washington Section strongly recommend that other Sections try to have Dr. Kettering appear at one of their meetings. They will be well rewarded.

Prior to the meeting, Dr. Kettering was tendered a dinner at the Mayflower Hotel, attended by the officers of the cooperating societies. Other guests at the dinner included Mr. Fred Zeder, Research Director, Chrysler Corp., and Admiral Harold G. Bowen, Director of the Navy Office of Research and Development.

The regular November meeting was held on Tuesday, the 27th, at the Pepco Auditorium with A. K. Phillippi, manufacturing engineer, Westinghouse Electric Corp., as the speaker of the evening. Mr. Phillippi's topic was "Metal Joining in Controlled Atmospheres (Furnace Brazing); Its Past, Present, and Future," with major emphasis placed on copper brazing.

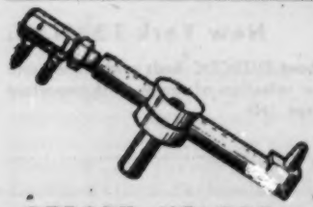
WESTERN MICHIGAN

One of the Section's most interesting and instructive meetings was held on Monday evening, December 3rd, at the Association of Commerce Cafeteria where dinner was served.

Roland H. Ogen, President of Aladdin Rod & Flux Mfg. Co., gave a demonstration of the welding of White Metal (Die Cast) and Aluminum. He was asked many questions which he answered in a very satisfactory manner.

WESTERN NEW YORK

"Fabrication and Welding in the Aluminum Industry" was the subject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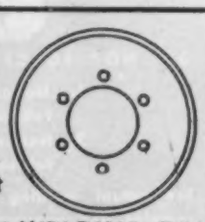
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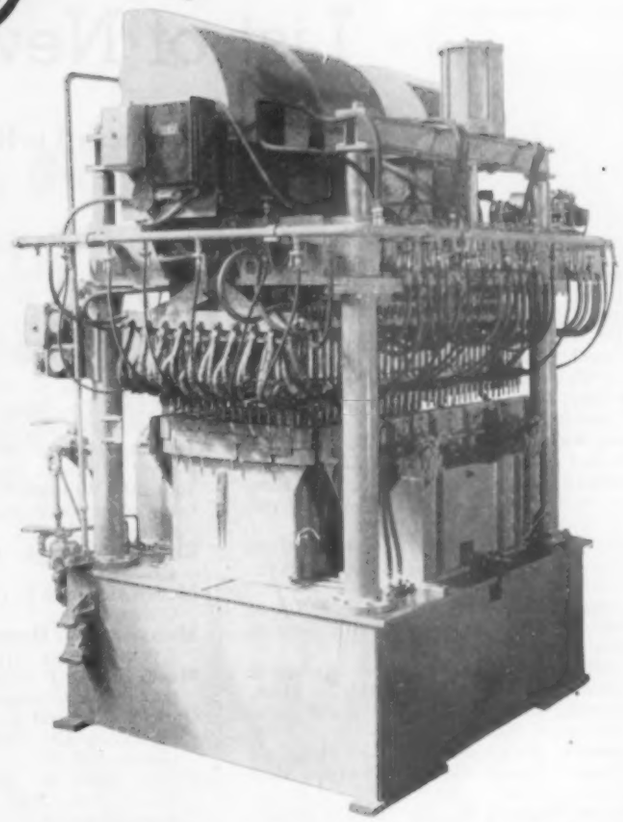

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presented by L. J. Benson, chief metallurgist, Parts Division of the Reynolds Metals Co., Louisville, Ky., at the November 30th meeting held at the 40 and 8 Club.

YORK-CENTRAL PENNSYLVANIA

R. F. Wyer, application engineer for the Electric Welding Division, General Electric Co., spoke on "Inert Arc Welding" at the November 7th meeting held in the Engineering Building, York, Pa.

R. D. Wasserman, President, Eutectic Welding Alloys Co., New York, spoke on "Eutectic and Low Temperature Welding" at the December 5th meeting. Dinner at Yorktowne Coffee Shop preceded the meeting.

List of New Members

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Alexander, Edward E. (C), 26 Holly Ave., Lynn, Mass.
Barrett, Robert F., Jr. (B), 16 Parkview Dr., Hingham, Mass.
Driscoll, Leo. B. (C), W. S. Young Co., 18 Webster St., Brookline, Mass.
Dwelley, Charles E. (B), 14 Clinton St., Cambridge 39, Mass.
Foss, Raymond H. (B), E. B. Badger & Sons Co., 75 Pitts St., Boston, Mass.
Freeman, Raymond C. (B), General Electric Co., 920 Western Ave., West Lynn 3, Mass.
Gale, Albert G. (C), c/o New England Trawler Equip. Co., 301 Eastern Ave., Chelsea, Mass.
Hollingsworth, Thomas D. (B), Nelson Sales Co., 150 Causeway St., Boston, Mass.
Nisbet, Frederick S. (B), E. B. Badger & Sons Co., 75 Pitts St., Boston 14, Mass.
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Symonds, Ralph F. (B), New England Trawler Equip. Co., 301 Eastern Ave., Chelsea, Mass.
Wyman, Richard W. (B), 12 Everell Rd., Winchester, Mass.

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Butterfield, Grifford (C), 57 White St., Bridgeport 8, Conn.
Lalli, R. A. (B), Lalli Truck Tank Co., Maddison Terrace, Bridgeport 6, Conn.

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Johnson, William F. (B), Johnson Welding Equip. Co., 2640 W. Van Buren St., Chicago 12, Ill.
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Matasovic, John L. (C), 1235 W. 95th St., Chicago, Ill.
Michalson, W. Harvey (C), 5110 Oakdale Ave., Chicago 41, Ill.
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Barger, Homer John, Lt. (jg), CEC, U.S.N.R. (B), 1681 Kahn Ave., Hamilton, Ohio.
Miller, Clifford Thos. (C), Miller Equip Co., 227 Race St., Cincinnati, Ohio.
Saelens, J. J. (C), The Linde Air Prods. Co., 2506 May St., Cincinnati 8, Ohio.
White, Harold M. (B), Box 125, R. D. 9, Cincinnati, Ohio.

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Lockwood, Frederick W. (C), 6014 Theota Ave., Parma 9, Ohio.
Pedley, Harold K. (B), 241 E. 218th St., Euclid 19, Ohio.
Sikorski, Henry J. (C), 10819 Morrison Ave., Cleveland, Ohio.

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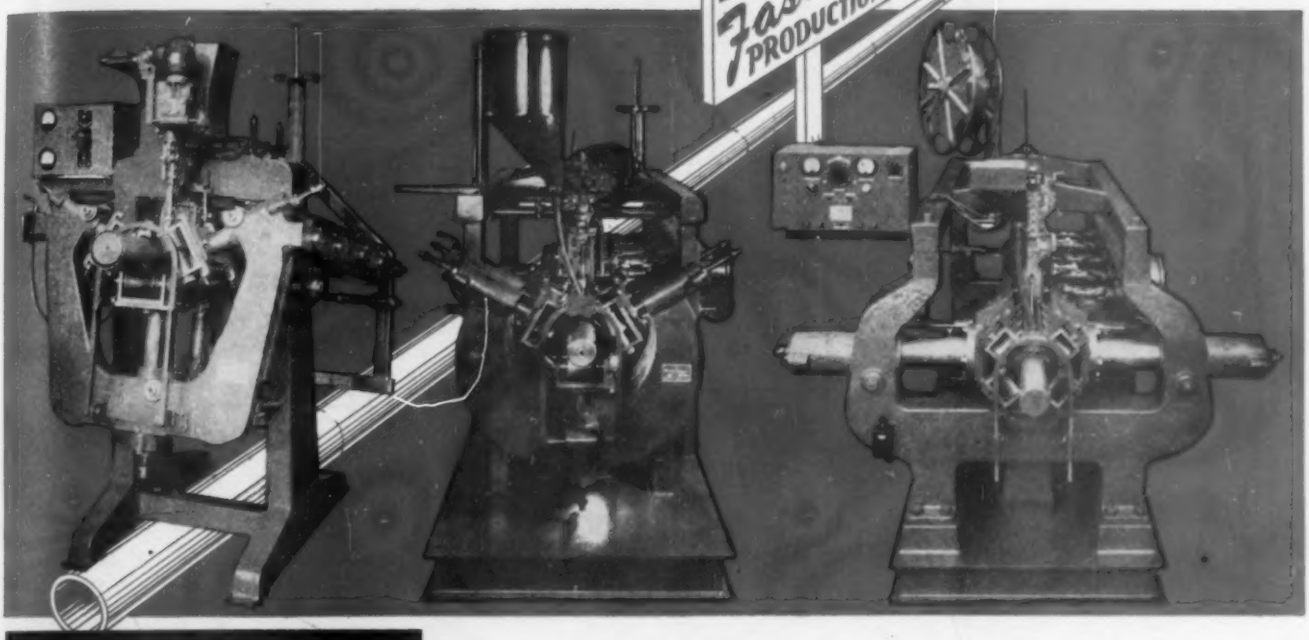

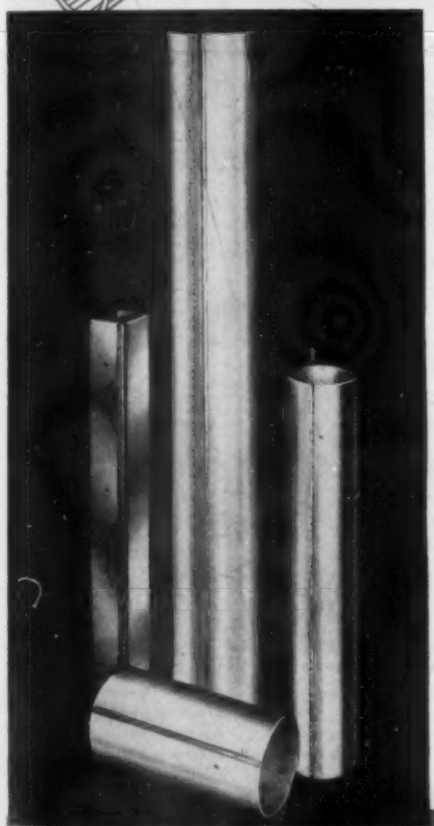

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